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Abstract

In the recent years co-opetition has emerged as a new theoretical concept, emphasizing the concurrency of competition and cooperation in business relationships. It is considered as an integrative bridge between older contributions which one-sidedly emphasize either competition or cooperation. However, the co-opetition theory is barely applicable for problems of relationships between enterprises because of structural and methodical flaws. Therefore a framework for the modelling of enterprise co-opetition is introduced. A definition for the term co-opetition and determinants of co-opetition models are introduced, which are external institutions, several industrial boundaries and time. An industrial supply chain is introduced as one of the industrial boundaries in co-opetition models that considers the impact of potential participants and distinguishes between individual customers and mass markets. A profit distribution rule is introduced for supply chains with individual customers, which considers the impact of excluded suppliers and can be used for the prediction of the outcome of auctions. It is shown for both mass markets and individual customers in how far stable agreements can be achieved, facing the problem of ubiquitous time-inconsistency of agreements. It is shown in which cases the introduced profit distribution rule recommends more stable negotiation outcomes than the Aumann-Drèze-rule and the Myerson-rule for coalition structures. Ideal-typical cases of industrial supply chains with mass markets and individual customers are simulated with the software “MATLAB”. Experiments are implemented with test persons via the internet with the software “z-tree”. These experiments are intended to verify the theoretical predictions about the negotiation outcomes and the agreement stability.

Notations

Abbreviations

a – boundary market price that leads to a quantity demand of 0;
A – action set;
A – agent;
A, B, C – agents in coalition;
AD – Aumann-Drčze-rule;
ADMCS – aumann-drčze-rule/ myerson-rule for coalition structures (identical for 3 agents);
B/N – brandenburger/ nalebuff;
BI – backward induction;
c – variable costs;
cart – cartel;
CG – coalition game;
CPNE – coalition-proof nash equilibrium;
d – degree of product heterogeneity;
ERP – enterprise ressource planning;
F – fixed costs;
G – game;
g – network/ subnetwork;
H – information set;
I – individual customer;
I.set – imputation set;
LAN – local area network;
M – mass market;
MATLAB – matrix laboratory;

MNE – multinational enterprise;
My – myerson-rule;
N – total number of persons;
n, I – number of people (function argument);
NG – network game;
NIE – new institutional economics;
NP – nondeterministic polynomial time (assessment of complexity);
NPV – net present value Investment;
NTU – non-transferable utility (games);
OOCS-rule – outside-option modified profit distribution rule for coalition structures;
p – price;
P – principal;
P – polynomial time (assessment of complexity);
P-A – principal-agent (theory);
Pcore – partitional core;
PV – present value;
q – quantity;
R, S – sub-coalitions;
ROI – return on investment;
s – strategy;
S – supplier;
SG – strategic game;
Sh – shapley-rule;
SNE – strong nash equilibrium;
t – time (function argument);
T – last point in time;
TAC – transaction costs;
TCP/IP – transfer control protocol;
TU – transferable utility (games);
u – utility;
x – profit of a particular agent or (sub-) coalition;
z-tree – zurich toolbox for readymade economic experiments;
Π, π – total profit, individual profit;
$\Re$ – finite partly ordered set;
v – characteristic function.

Contents

[1]The annexes are supplied in the enclosed compact disc

Introduction

Problem definition

The ambivalence of competition and cooperation in the relationships between enterprises is a phenomenon that has been investigated scientifically in several aspects. However

1. there is no unified theory,
2. that is based on appropriate mathematical instruments,
3. which enables the deployment of computers, in order to calculate and predict various aspects of such relationships.

This is the problem that the thesis is intended to solve. It deals with several models of competition and cooperation which are verified by the implementation of software that is developed for this purpose.

Topicality of the research

The research that is implemented in the thesis is topical for the following issues:

1. Co-opetition in international business,

2. Development of the co-opetition theory,
3. Negotiation power and stability of agreements,
4. Long-term perspectives about the advancement of enterprise software.

1. Co-opetition in international business

Co-opetition is a neologism uniting the terms competition and cooperation. It emphasizes the ambivalence of competition and cooperation in the relationships with all other enterprises in the industrial supply chain, which are the suppliers, customers, competitors and providers of complementary goods.

In the past decades supra-regional, international and global markets have gained tremendous importance. The increasing interdependence of economic actors from different regions, countries, etc. is one of the various facets of "globalization". Some important reasons for this development are the integration of the most European countries into a common market, technological progress like the emergence of internet and significant economic development in Eastern Europe, the CIS states, PR China, India and Latin America (Figueira and Greco 2005; Ginevičius and Podvezko 2008a; Liu 2009; Srnka and Koeszegi 2007; Šijanec Zavrl et al. 2009).

However this kind of "globalization" has led to

1. increased complexity and unpredictability:
   - of the development of the business environment,
   - of the relationships with business partners' and
   - of the own interests,
2. a declining importance of national states, i.e. declining possibilities of contract assertion in international agreements (legal security).

Thus, enterprises make strategic decisions in international business, while facing increasing complexity, unpredictability and lack of legal security.

Co-opetition research, which is connected with microeconomics, game theory, new institutional economics and strategic management, enables deciders in enterprises to gain more profound understanding about enterprise relationships in industrial supply chains, the influence factors of negotiation power, the stability of agreements, etc. This knowledge may help an enterprise in future to develop better business strategies in international business.

2. Development of the co-opetition theory

The co-opetition theory is still in an early stage of development. Because of structural and methodical flaws the co-opetition theory is barely applicable for problems of relationships between enterprises. There is no standardized and accepted definition or framework for co-opetition models. Furthermore it is not clear, in which way game theory is applicable.

Therefore the development of a new foundation of the co-opetition theory and the formulation of determinants for co-opetition models is an important and contemporary scientific contribution. It should be focused on the various relationships within an industrial supply chain and the impact of enterprises that are excluded but nevertheless have impact on the relationships, particularly regarding the negotiation outcomes and the stability of agreements (Plebankiewicz 2009; Ulubeyli and Kazaz 2009).

3. Negotiation power and stability of agreements

In the continuously growing international business national states lose their importance in reference to the assertion of contract fulfilment. Particularly in situations where there is no reliance on state institutions, which may assert the fulfilment contracts, the understanding of negotiation power is crucial (Ginevičius and Krivka 2008; Peldschus and Zavadskas 2005; Zavadskas and Turskis 2008).

Negotiation power and the stability of agreements are important issues of game theory, which is the theory of strategic interaction. It would be an important scientific contribution to show, in how far enterprises that are outside the industrial supply chain influence negotiations and the stability of agreements, and in how far negotiation outcomes can be predicted.

4. Long-term perspectives about the advancement of enterprise software

In the previous decades, enterprise resource planning (ERP) software has developed tremendously. It has become crucial for the administration and controlling of any enterprise division. Important parts of an ERP system are the inventory management and customers' relationship management. However, all the automating has been only successful for processes that do not require actual intelligence. As soon as decisions are necessary, which are based on the profound assessment of the environment, IT systems cannot provide much support yet. Particularly the strategic decision making, has only be supported yet, for instance by data mining software (software that collects automatically particular relevant information in the internet). It cannot be expected from IT systems in the near future that they will be able to make independent decisions about business strategies.

However in the long run, the progress in artificial intelligence might open up the possibility for IT systems to understand and assess its business environment, and to make decisions with the intention to maximize its owner's utility.

In this case the game theory explains the possibilities of rational decision making.

Aims of the work

The aim of this thesis is the development of a new framework for models of enterprise co-opetition, in order to facilitate the development of best-possible business strategies. A more profound understanding of

- enterprise relationships in industrial supply chains,
- the influence factors of negotiation power and
- the stability of agreements

is provided by a variety of theoretic developments at the field of co-opetition. The developed theory is depicted by simulations and confirmed by internet based experiments.

Tasks of the research

The tasks of the research are as follows:

1. to provide a comprehensive state-of-the-art overview and to determine the frame of further co-opetition research
2. to develop the theory of co-opetition by

- providing a new definition of co-opetition and a framework for co-opetition models in which game theory is used as mathematical instrument,
- delving into the details of the introduced co-opetition framework by developing an “industrial supply chain”,
- providing a profit distribution rule that considers the possible influence of excluded agents in dynamic setting that can be used as prediction for the outcome of auctions,
- examining the stability of negotiation results under various prerequisites for industrial supply chains with mass market customers or individual customers,
- simulating the profit distribution in business relationships with ideal-typical parameters and

3. to verify the model predictions about negotiation outcomes and agreement stability for games with mass markets and individual customers in experiments with test persons via the internet.

Deployed software

– MATLAB:

is a mathematical program for numerical and symbolical calculations. It is used for the calculation of ideal-typical examples, algebraic derivations and all graphs in the chapter 3 that depict the results of the calculations and of the evaluated empirical data.

– z-tree:

is a software that has been developed at the University Zürich. It allows to develop and to carry out experiments in game theory and microeconomics. It is versatile and is handled over a graphical surface with a proper programming language.

– Microsoft Excel:

it has been used for storing and analysing experimentally recorded data.

- Microsoft Word: is the used program for the writing of the thesis and all publications.
- Microsoft PowerPoint: is the used program for the making of the majority of the figures.

Methodology of research

Table 1 shows the structure of the thesis and which methods of research have been implemented. The chapters are assigned to the deductive approach (conclusion from the general to the particular) and to the inductive approach (conclusion from the particular to the general). For the subchapters of the 2^{nd} order the methods of research are shortly listed.

Table. 1. Structure of thesis and methods of research

<table>
<tr><th></th><th>Chapter</th><th colspan="2">Subchapter</th><th colspan="2">Method of research</th><th>Remarks</th></tr>
<tr><td rowspan="10">Deductive approach</td><td rowspan="4">1. Literature overview</td><td rowspan="2">1.3</td><td>Older contributions concerning business relationships</td><td colspan="2">Literature research & analysis, restricted by relevance</td><td></td></tr>
<tr><td>Co-opetition</td><td colspan="2">Comprehensive research & analysis of contributions</td><td></td></tr>
<tr><td>1.4</td><td>Game theory for co-opetition</td><td colspan="2">Literature research & structuring, restricted by relevance</td><td rowspan="2"></td></tr>
<tr><td>1.5</td><td>Frame of further research</td><td colspan="2">Result of search for lacks and flaws in the contemporary theory</td></tr>
<tr><td rowspan="5">2. Development of theory</td><td>2.1</td><td>Foundations of co-opetition</td><td rowspan="2">Experimental verification:</td><td rowspan="2">no</td><td rowspan="2"></td></tr>
<tr><td>2.2</td><td>Industrial supply chains</td></tr>
<tr><td>2.3</td><td>Time-inconsistency</td><td rowspan="2"></td><td rowspan="2">indirect</td><td rowspan="2">Implicitly considered
in the experiments</td></tr>
<tr><td>2.4</td><td>Profit distribution rule</td></tr>
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2.6</td><td>Prediction of negotiation results, stability of agreements</td><td></td><td>direct</td><td>Formulation of statements that have to be proved</td></tr>
<tr><td rowspan="3">3. Verification of theory</td><td>3.2
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<tr><td rowspan="2">Inductive approach</td><td>3.2
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z-tree</td><td></td></tr>
<tr><td>3.2
3.3</td><td>Collection and evaluation of experimental data</td><td colspan="2">Deployment of software:
MATLAB, MS Excel</td><td></td></tr>
<tr><td></td><td></td><td>3.4</td><td>Comparison of theoretical predictions (2.5, 2.6) and empirical data (3.2, 3.3)</td><td colspan="2">Synthesis of research results</td><td></td></tr>
</table>

The scientific novelty

- The framework of co-opetition models: new definition of co-opetition and determinants of a co-opetition model
- “Industrial supply chain”: further development of Porter’s “5 forces driving industrial competition” and Brandenburger and Nalebuff’s “Value net”, integration of the “industrial supply chain” into the co-opetition framework
- Comprehensive analysis of supply chain networks with 2, 3 and 4 agents
- Explication of the ubiquity of time-inconsistency of agreements and the possible resulting instability
- Development of the profit distribution rule: “outside-option modified profit distribution rule for coalition structures (OOCS)”, explication of the cases when the OOCS-rule is superior in comparison with the Aumann-Drèze-rule and the Myerson-rule for coalition structures
- Analysis of the contrary incentives in industrial supply chains with mass markets to act non-cooperatively and cooperatively
- Prediction of negotiation results (e.g. the outcomes of auctions) in industrial supply chains and individual customers with the developed profit distribution rule
- Analysis of the stability of agreements among 2 enterprises with and without outside-option
- Implementation of game theoretic and microeconomic experiments with the program “z-tree” over the internet in order to confirm (or disprove) the introduced theory, as a step towards automatic prediction systems in the future.

Practical value

The thesis contributes to better theoretical and practical control over negotiations, the prediction of negotiation results and agreement stability in different settings. In the future, enterprise software systems will make intended rational decisions, which are relevant for business strategy. The thesis is a contribution in this direction.

In this sense the thesis provides a better understanding of strategic management and business relationships in general.

Approbation

The author has published 5 scientific papers:

Stein, H. 2010a. Allocation rules with outside option in cooperation games with time-inconsistency. *Business, Economics and Management*, 10(1): 56–96.

Stein, H. 2010b. Literature overview on the field of co-opetition. *Verslas: Teorija ir Praktika. Business: Theory and Practice*, 11(2): 256–265.

Stein, H; Ginevičius, R. 2010a. New co-opetition approach for supply chain applications and the implementation of a new allocation rule. *6th International Scientific Conference, May 13–14, 2010, Vilnius, Business and Management 2010*: 1092–1099.

Stein, H.; Ginevičius, R. 2010b. The experimental investigation of the profit distribution in industrial supply chains with an outside option. *Technological and Economic Development of Economy*. 16(3): 487–501.

Stein, H.; Ginevičius, R. 2010c. Overview and comparison of profit sharing in different business collaboration forms. *Journal of Business Economics and Management*. 11(3): 428–443.

The author has participated and presented his research at 2 scientific conferences in Lithuania:

1. ”Co-opetition – The new paradigm in management”, at the “5th International Scientific Conference, Business and Management 2010”, May 15–16 2008.
2. “New co-opetition approach for supply chain applications and the implementation of a new allocation rule”, at the “6th International Scientific Conference, Business and Management 2010”, May 13–14 2010.

The dissertation has 190 pages, 61 figures and 29 tables, a list of references, a list of the author’s publications and an appendix A–E.

1

State of the art of co-opetition and game theory as its mathematical instrument

After explaining the placement of the research question into the economic sciences, and the bounds on the ideal of the homo economicus, a comprehensive state-of-the-art overview is given over co-opetition and related elder theoretical contributions. A profound overview over these parts of game theory is given that can be relevant as mathematical instruments for co-opetition models. Finally, the frame of the further research is explicated.

1.1. Placement of the research question into economic sciences

The term “economics” comes from the Ancient Greek word οίκονομία (oikonomia, "administration, management of a household") and is a connection of οίκος (oikos, "house") and νόμος (nomos, "custom" or "law"). Thus the literal meaning is about "rules of the house (hold)". Lionel Robbins (1932) defines economics as "the science which studies human behaviour as a relationship between ends and scarce means which have alternative uses." In the context of economic sciences an independent decider is called “agent”. Sometimes “player” is used as synonym for “agent”. Economic agents make or intend to make decisions in a rational way though rationality is often not perfect achievable. Additionally economic agents basically regard an increase of wealth or more consumption as the cause of more satisfaction or happiness. In opposite, happiness by asceticism or the self-abandonment for an ideological or political cause is neglected in economic science, which is a clear feature of distinction from other social sciences. Thus the economic agent is characterized by:

- the intention to behave rationally,
- positive assessment or perception of more wealth or consumption.

Contemporary economics is of extreme diversity. There is a variety of directions that compete but also complement each other. Some important directions are listed below:

- neoclassical economics (welfare economics, equilibrium theory, etc.),
- game theory/microeconomics,
- new institutional economics (Principal-Agent, transaction cost theory, etc.),
- financial economics (financing, banks, insurances, etc.),
- strategic management (investment decisions, product and service related decisions, etc.),
- macroeconomics (economic policy, monetary policy, public finance, etc.),
- empirical sciences (statistics, econometrics, economic history, etc.).

These directions result from centuries of scientific work at universities and other scientific institutions and the experience of humankind. Usually the terms of the directions are not precisely defined and there is much overlapping. Neoclassical economics are the simplistic and traditional approach with a very strong focus on rational behavior. Game theory and microeconomics have their origins in the neoclassical economics. Nowadays microeconomics can be regarded as game theory that is applied in economics. However game theory is not restricted to economic sciences. New institutional economics are also based on neoclassical economics. There is a focus on problems of information asymmetry between business partners and on transaction costs. Financial economics is about the optimal distribution of financial resources regarding insecurity, but also about the role of banks and insurances. Due to the importance of rationality it is closely connected to neoclassical economics as well.

Macroeconomics regard big economic systems like states. It is a patchwork of very different approaches in order to understand and support economic policy, monetary policy, public finance, etc. Macroeconomics have aggregated and simplified contributions from neoclassical economics and microeconomics, but also have approaches that are based on empirism, like statistic, econometrics and economic history. While the theoretical approach is "deductive" (from the general case to specific), the empirical approach is "inductive" (from specific case to general). Figure 1 depicts the relationships between the fields of economics. Fields which are relevant for co-opetition are framed.

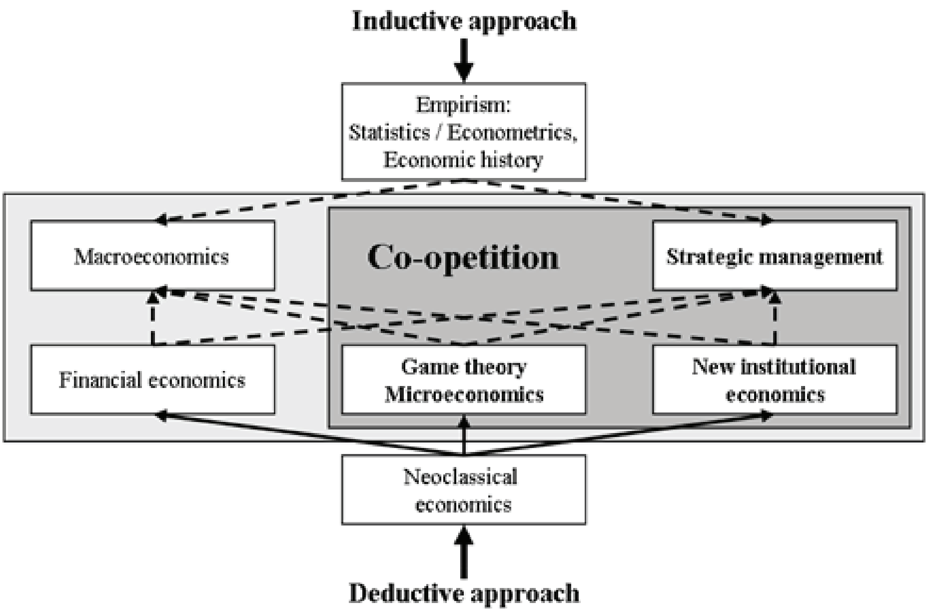


Fig. 1. Relationships between the fields of economics, marking of fields that are relevant for co-opetition (by the author)

1.2. Bounds on the homo economicus principle and time-inconsistency

Decisions in economics are only a small part of the general philosophical problem that deals with decision making (Shubik, 1982). The "homo economicus", which is the ideal of the rationally thinking and acting person, is predominant in the economic theories. Though this ideal is barely achievable, it represents the target-state for the normative approach. Figure 2 gives an overview over the characteristics of a "homo economicus", i. e. a perfectly rational decider:

“Homo economicus”: the rational decider
- **Individual rationality:**
  perfect problem understanding, consideration of all consequences of decision
- **Preference orders:**
  axioms of completeness and transitivity, ordinal scaling (if no further assumptions)
- **Assumption of cardinal scaling in game theory:**
  intensity of preferences (monetary value) is known
- **Aggregation of preferences:**
  attempt of ≥ 2 agents to achieve **Pareto-efficient** (collectively rational) agreement

Fig. 2. Homo economicus” – postulate of perfectly rational decider

The “Homo economicus” postulate requires from the agent perfect individual rationality. This means particularly:

- Knowledge and understanding of the problem and its implications
- Ability to optimize
- Clear preferences
- Indifference to logically equivalent descriptions of alternatives and choice sets.

The agent has to overview all consequences of his decisions perfectly and must understand what the best possible decisions are.

He must be able to give a preference order to all possible strategies and must not be influenced by different but equivalent descriptions of the problem. In order to recognize his preference order, the agent compares all alternatives pairwise (Güth 2007). A preference order is an n-tuple $(\omega, \omega', ..., \omega^n)$ from the set Ω^n and fulfils the axioms “completeness” and “transitivity”:

- Completeness: the decision maker determines the preference relations for all pairs of alternatives
- Transitivity: for the three elements $\omega, \omega', \omega'' \in \Omega$ the following is fulfilled: if $\omega \succ \omega'$ and $\omega' \succ \omega''$ then $\omega \succ \omega''$.

E.g. a general preference order of an agent with 5 alternatives is of the form: $\omega \succ \omega' \succ \omega'' \succ \omega''' \succ \omega''''$. So far nothing is said about the intensity of the preferences. Therefore in the general case only ordinal scaling (first, second, third, etc.) is justified.

However models with ordinal preferences are connected with fundamental problems (Binmore 1994):

- Intractability: if an agent cannot recognize the exact value of his decision, complexity increases tremendously.

- General impossibility of preference aggregation (impossibility theorem, Condorcet 1785; Arrow 1970): it is generally impossible to find commonly accepted (no dictator) agreements for ≥ 2 players and ≥ 3 alternatives, if the preferences are ordinal, and the rationality requirement should be fulfilled.

Due to these problems, it is assumed that all agents exactly understand the monetary values of their decisions. Von Neumann and Morgenstern (2007) have determined cardinal preferences as the standard in game theory. Thus in opposite, the social choice theory attempts to deal with ordinal preferences.

The crucial criterion for preference aggregation in order to make an agreement is Pareto-efficiency (or Pareto-optimum, Pareto-dominance, collective rationality) that represents unanimity among the agents. If an allocation (e. g. distribution of goods among agents) is Pareto-efficient, no agent can be put into a better position, without worsening the position of another agent. That means that the total profit is distributed among the agents and nothing is left. If all agents participate, "welfare is maximized". However Pareto-efficiency can also refer to a subgroup of agents (component-Pareto-efficiency, link-Pareto-efficiency). In this case it is not welfare maximizing. Pareto-efficiency has no connection to fairness considerations.

Figure 3 shows the typical human problems in the connection with rationality (Rubinstein 1998), contemplation and information:

Problems with rationality: contemplation
- **Quantification:**
  Assessment of values of relevant elements, and recognition of the dependencies between elements
- **Prospect theory:** endowment effect, loss aversion, reframing effect
- **Myopia in dynamic setting:** incapability of farsightedness
- **Complexity problem:**
  complexity classes of algorithms, contemplation costs and possibilities of **simplification**

Problems with rationality: information
- **Imperfect information:** insecurity about other agents, insecurity about environment

Fig. 3. Human problems with rationality: contemplation and information (by the author)

Human problems with rationality: contemplation

Human decisions and behaviour are in general not perfectly rational. However this does not mean that they are chaotic. Simon (1994) introduced the distinction between substantive rationality and procedural rationality.

Substantive rationality means behaviour that "is appropriate to the achievement of given goals within the limits imposed by given conditions and constraints".

Therefore all thinkable information and implications must be considered for strategy determination. Simon declares that substantive rationality is generally not achievable. In opposite, behaviour is procedurally rational if it is the outcome of appropriate deliberation. Roughly said, procedural rationality is the attempt to behave rationally (Sobotka and Rolak 2009). Impulsive decisions without intervention of thoughts are forbidden. Procedural rationality is also called intended rationality.

In connection with the bounded ability of contemplation, the following has to be considered:

- Quantification of factors, events or processes (Chen 2006),
- Problems of prospect theory,
- Myopia in dynamic setting,
- Problems of complexity (Rubinstein 1998).

It is often difficult to quantify, i. e. to count or measure relevant factors, events or processes (Figueira and Greco 2005; Srnka and Koeszegi 2007). The

- values of the relevant elements have to be assessed (Aumann 1970) and
- the dependencies between elements have to be identified.

The quantifiable components of a problem have to be separated from the non-quantifiable ones. In the best case it is possible to depict a problem perfectly in a formal way and quantify all elements on a cardinal scale (determination of monetary value). However if this is not possible, it must be assessed in the particular case in how far approximations lead to usable models and results.

The prospect theory of Kahneman and Tversky (1979) deals with systematic mistakes of human contemplation if not all information is known. These are typical mistakes that are approved by experiments:

- Overconfidence bias: people often overestimate their ability of understanding a situation and determining the right strategy,
- Endowment effect/loss aversion: people valuate thing higher if they possess them,
- Pseudo-certainty/reframing effect: people's decisions are often influenced by the way an uncertain situation is expressed.

Arieli (2008) has given new important contributions at the field of systematics of incorrect inferences, like the systematic human weakness to assess one's own willingness to pay and how it can exploited by smart negotiation.

In dynamic setting, myopia is the incapability to understand and predict all future implications of one's own decisions (Dutta et al. 2004). Especially the stability of one-shot agreements might not be ensured if the game is dynamic. Connections between the agents may fall apart and other connections occur. The questions "Where will it all lead? Is the end result good or bad for me?"

(Aumann and Myerson 1988) brings out the claim of farsightedness, i.e. the prerequisite of rationality in decisions with dynamic implications. Complexity of problems restricts both the ability of humans and machines to make rational decisions. Particularly

- if the number of players increases,
- if information is incomplete,
- if players deceive,
- or the game is dynamic etc.,

complexity can increase tremendously. It is barely possible to measure the effort that an agent puts into contemplation. Therefore, in order to classify the complexity of game theoretic models, the approach of complexity classes of algorithms is borrowed from informatics. The most important complexity classes are (Steimle 2008; Nisan, Roughgarden 2007):

- Polynomial-time algorithm (P-class),
- Non-polynomial-time algorithm (NP-complete class),
- Exceeding of NP-complete class (NP-hard class).

P-class problems are the easiest ones. There exists an algorithm that needs a number of calculation steps that can be expressed by a polynomial function, so that it can deal with big numbers. Problems of NP-complete class need an exponential function and therefore basically cannot deal with high numbers. Problems of NP-hard class are of that high complexity that it is not known whether there exists a general formula that estimates the computation steps. Usually, the finding of solutions in game theory is in the NP-complete class. In network games many problems are even in the complexity class NP-hard. However, the computer verification of an already found solution is mostly "just" in the simpler P-class.

If contemplation is connected with expenses, thinking about the problem becomes to a part of the problem in a broader sense. Then it is rational to simplify the problem. Problems of NP-complexity (exponential complexity growth) or NP-hardness (dubiety whether complexity is quantifiable) need simplification in the case of big numbers. Roughly said simplification can be reached by:

- implication (e. g. unification of agents to one representative),
- approximation (e. g. using of cardinal scaling).

Simplification in order to reduce complexity generally does not reduce the explanatory power of a model. Friedman (1966) argues that models can be useful even if they are based on wrong (or simplified) assumptions. Therefore models should be evaluated only with regard to the application. An example is ancient sea navigation that was based on earth-centred astronomy. Hence, incorrect assumptions are not necessarily a knock-out criterion in game theory.

Human problems with rationality: information

Game theory has various approaches that deal with insecurity. Agents have to understand consistently their own risk attitude when they face

- incomplete information about the moves and attitudes of other players (imperfect information),
- incomplete information about external factors or environment.

In the case of incomplete environment information, Harsanyi (1967) has proposed to depict nature, as if it was an agent.

1.3. Co-opetition: The state of the art

1.3.1. The competitive and the cooperative perspectives in economic theory as the delimitation of the co-opetition perspective

Before the introduction of co-opetition, business theory has been emphasizing either on the competitive or on the cooperative aspect of business relationships (Stein, Ginevičius 2010c). The competitive perspective has its roots in the neo-classical economics. Important representatives are:

- Schelling with his seminal book "Strategy of conflict" (1960)
- Porter's "Competitive strategy" (1980) and
- The transaction cost economics (Coase 1937; Williamson 1985) (part of new institutional economics).

Important representatives of the cooperative perspective are Contractor and Lorange (1988) by explicating the benefits of business cooperation.

1.3.1.1. Schelling's "Strategy of conflict"

Schelling's book "Strategy of conflict" (1960) is an early contribution referring to the transfer of game theory, i. e. the mathematical theory of strategic interaction, to a practice oriented business theory where independent agents interact and each of them pursuits his own targets.

Schelling argues that the traditional "zero-sum games" are only an extreme case of interaction and represent situations of "pure conflict". In "variable-sum games" the agents have to collaborate. However collaboration is a certain form of selfish behaviour.

If agents have to collaborate without having the possibility of direct communication, one agent starts to assume which decision is plausible for the other agents. Thereby he assumes that also all other agents ask the same questions about the respective other ones. Even in situations where secrecy is important, it might become essential to signal one's intensions and to achieve a "meeting of minds".

It is a process of mutual expectations that converges in the focal point (or Schelling point), a non-mathematical concept that is very close to the Nash-equilibrium or to concepts that are based on the Nash equilibrium (refinements), like the iterated elimination of dominated strategies (Vega-Redondo 2003).

Schelling claims that the "human aspects of game theory" have to be regarded with at least as much attention as the "mathematical aspects". By that he criticizes the postulate of the perfectly rational decider that was prevalent at that time and the possibility to describe human behaviour just by mathematical means. However, in modern game theory the rationality postulate is weakened to "intended but bounded rationality" (Simon 1996; Rubinstein 1998). Schelling's focal points do not necessarily need the mutual assumption of the others' rationality.

Schelling analyses bargaining procedures thoroughly and recognizes the sources of power in a negotiation. Thereby credible commitments have a crucial impact on the bargaining position. He claims that a negotiator gains power, if he can convince his opponent that he has no choice except of offering alternatives that are less beneficial to him. This can be achieved:

- by making a contract with a third party, so that a better offer becomes very costly,
- by making a commitment in connection with a ceremony or a "belief system" that prevents one from offering a higher price or
- by a situation where the negotiator is punished if he makes a better offer, in the case that he negotiates in behalf of someone else (e. g. leadership, union, etc.).

Thus power in bargaining comes from sacrificing one's full range of freedom and options, the "power to bind oneself".

"Strategy of conflict" can be regarded as the first book about co-opetition. It highlights the idea that selfish agents collaborate as long as it is in their interest. This implies the idea of ambivalence of competition and cooperation. Schelling transfers the Nash-equilibrium and the refinements to focal points, a non-mathematical concept. This can be regarded as a step towards a more practice oriented business theory.

1.3.1.2. Porter's "Competitive strategy"

Porter has introduced in his book "Competitive Strategy" (1980) a comprehensive collection of ideas how to understand the forces that determine industry structures and the competition within and between industries. Some important issues are:

- the forces driving industry competition,
- the generic strategies of competition,
- the determinants of return on investment (ROI) and strategic groups,
- vertical integration vs. long–term contracts.

Porter describes 5 "forces driving industry competition":

- Rivalry among existing firms,
- Bargaining power of suppliers,
- Bargaining power of buyers,
- Threat of substitute products or services,
- Threat of new entrants.

He claims that competition in an industry goes beyond the existing agents and encompasses the supply chain and potential rivals.

In the relationship with competitors, Porter defines 3 "generic strategies" of competition:

- Overall cost leadership, e. g. by constructing efficient-scale facilities, vigorous pursuit of cost reductions from experience, etc.
- Differentiation of product and service in order to create "something that is perceived industry wide as being unique".
- Focus on particular buyer group, segment of the product line, geographic markets, etc.

Competitors, i. e. enterprises that pursue similar strategies like the supplement of the same market, can be assigned into "strategic groups". Within a strategic group, competition can be particularly harsh and more "strategic distance" usually lessens severity of rivalry. The determinants of the ROI of an enterprise are divided into those of the entire industry, the strategic group and the position within a strategic group:

- General industry characteristics,
- Strategic group characteristics: Mobility barriers, severity of rivalry, Negotiation power,
- Position of company within strategic group: Competition intensity, (Size of company within group), (Ability to implement strategy in operative manner).

The potential benefits and costs of vertical integration are discussed, i. e. the internalization of supplier or retailer operations. If an enterprise buys its own supplier or retailer, this can lead to benefits like:

- economies of combined operations, internal control and coordination,
- economies of collecting information,
- economies of avoiding the market and stable relationships.

On the other hand, this can be connected with disadvantages like:

- the costs of entering new markets and overcoming mobility barriers,
- higher fixed costs, reduced flexibility to change partners and higher exit barriers.

Long-term contracts are proposed as an alternative to vertical integration: "A firm should always consider the option of contracting with an independent entity to achieve the same benefits as integration, especially when the risks and costs of integration are great. One of the pitfalls in vertical integration is to be beset by its costs or risks when many of the benefits could have been achieved through more clever dealing with outside parties".

Porter's perspective is that competition is the crucial characteristic of business relationships. Even if cooperation emerges, it is based on non–cooperative strategies. In this point Porter refers to Schelling's "focal points". Porter explicates the advantages of "vertical integration", and therefore emphasizes the competitive character of relationships inside a supply chain.

However, Porter shortly presents "long-term contracts" as an alternative to vertical integration due to possible costs and risks. This is a short reference to the incentives that enterprises might have in order to cooperate and a moderation of the purely competitive point of view that is predominant. Hence, it can be regarded as a short switch by Porter from the purely competitive perspective to the co-opetitive one.

1.3.1.3. The new institutional economics

The new institutional economics (NIE) is a collection of fields where the focus is on "institutions" instead of "primitive" rational deciders. Institutions are systems of rules:

- which are invented in order to regulate collaboration and exchange in a complex and insecure world,
- which can be valid over a longer time for many people,
- whose obedience has to be asserted.

Examples for institutions are contracts, markets, enterprises, but also states, cultural groups, etc. There are two approaches in NIE that are particularly important in order to show cooperative relationships from different perspectives. These approaches complement each other but partly overlap:

- Transaction cost theory,

- Principal-agent theory.

Dagnino and Padula presents the "transaction costs economics" as an important representative of the "competitive perspective". This paper additionally regards the "principal agent theory" as important in this context as well, particularly in the context of negotiations and situations with incomplete information.

The main idea of the transaction cost economics (TAC) (Coase 1937; Williamson 1975, 1985) is that each transaction is connected with expenses. Williamson is the Nobel Prize laureate in economics of 2009. A transaction is an agreement, communication or action between two separate entities or persons, often involving items of value, such as goods, services, money or information. Transactions can be characterized particularly by frequency:

- unique, rare, frequent with known end, frequent without known end, etc.
- insecurity,
- the number of involved people,
- specificity.

There is a multiplicity of kinds of specificity, like:

- Uniqueness of product or service,
- Location specificity,
- Specificity of capital equipment,
- Specificity of customer,
- Brand specificity,
- Reliance,
- Learning.

The using of a market and of an enterprise hierarchy are both origins of transaction costs. Williamson explains transaction costs as the economic analogy of "friction" in physics (Göbel 2002). In market transactions these are the ex-ante-costs:

- search and information costs,
- bargaining costs.

These are the ex-post-costs:

- policing costs,
- enforcement costs,
- adaption costs.

After the TAC, relationships between enterprises (i. e. in supply chains) and within enterprises have to be established with governing and monitoring structures in a way that the transaction costs are minimized. Though transaction costs may occur is almost each context, particularly the bargaining, policing and enforcement costs are connected with selfish behavior. Therefore the TAC represent a competitive perspective.

The principal-agent theory (P–A) refers to the relationship between an agent that looks for a problem solution (principal) and an agent that proposes the solution (Jensen 1976). The major problem between a principal and an agent is the information asymmetry, i. e. the incomplete information of the principal. The agent who proposes the problem solution can hide relevant information and therefore has the possibility of cheating. The principal-agent theory is relevant in

- negotiations and
- the realization of contracts.

There is a multitude of approaches in order to enforce an agreement and handle the agency problem, like:

- bureaucratic control (i. e. hierarchy),
- information system before contract conclusion: screening (Stiglitz 1975),
- information systems after contract conclusion: monitoring of the agent's action and information (e. g. controlling, time registration, milestones, etc.) (Spence 1973),
- incentives (e. g. performance dependent salary, etc.),
- enterprise culture,
- reputation or
- reliance.

As this enforcement is connected with transaction costs, a P-A problems can be part of a TAC problem.

The P-A theory is relevant in cooperative relationships, like in supply chains or among complementors. By referring to the possible opportunistic behavior of the partner, who has the advantage of having more information, it emphasizes an important non-cooperative aspect of cooperative relationships.

1.3.1.4. The cooperative perspective

Contractor and Lorange (1988) offer a view on business relationships that emphasizes the benefit of cooperation. Contractor and Lorange regard their approach partly "as a reaction to the competitive approach" (Dagnino and Padula 2002). "The sources of economic value creating and the roots of firms' superior performances are located within the structure of firms' interdependence." Value creation is a joint process that takes place among business partners. The mutual dependence is regarded as a “strong antidote” against the risks of opportunistic behaviour and a powerful incentive to act cooperatively.

- Risk reduction by:
  - Spreading the risk of a large project over more than one firm,
  - Enabling diversification of the product portfolio,
  - Enabling faster entry and payback,
  - cost “subadditivity” (the cost to the partnership is less than the cost of investment by each firm alone).
- Economies of scale and/or rationalization, by lower average costs from larger volume, lower costs by using comparative advantage of each partner.
- Technology exchanges, e. g. through the exchange of patents.
- Reducing competition by establishing joint ventures, etc.
- Overcoming government-mandated trade or investment barriers: receiving the permission to operate as a “local” entity because of a local partner or satisfying local content requirements.
- Facilitating initial international expansion by benefiting of local partner’s know–how.
- Vertical quasi-integration advantages of linking the complementary contributions of the partners in a supply chain, what can mean the access to materials, technology, labour, capital, distribution channels, etc.

Contractor and Lorange represent the opposite delimitation of the co-opetition perspective. By focusing on the potentials and advantages of cooperation, they provide arguments against opportunistic behaviour, e. g. the exploitation of fraud possibilities.

1.3.2. Literature overview of the co-opetition theory

1.3.2.1. Brandenburger and Nalebuff’s book “Co-opetition”

B/N explain “co-opetition” as an approach that intends to explain competition and cooperation in business networks in the spirit of game theory. The idea is to apply game theory to solve problems that are connected with business relationships and supply chains. However game theory is not introduced explicitly.

B/N focus on the ambivalence of competition and cooperation in “value nets”. “Value nets” are an extended notion of supply chains where competitors and agents with complementary offers are considered. It must not be confused with the “value chain” inside of enterprises that was introduced by Porter (1985). Even if two enterprises act as competitors at a market, there can be various possibilities for them to cooperate, either by not attacking each other, or by tacit price collusions, etc. On the other hand, cooperation partners generally compete in the question of profit sharing. B/N define five elements of a game as basic:

- Players,
- Added value,
- Rules,
- Tactics,
- Scope.

In the thesis the word "agent" is used to describe an independent economic decider. "Player" is only used when the original term is important. It is regarded as a rather informal term. The initial letters yield the catchy word "PARTS". It rather shows the wish to get a slogan for the "co-opetition" approach than a profound structuring. Nevertheless, B/N use the "PARTS" elements as crucial criteria.

Players (agents)

<u>**Players (agents)**</u>:
•**Value net:** competition and cooperation with
- competitors ("win-lose-relationships")
- complementors, suppliers, customers ("win-win-relationships")

•**Changing the cast of agents:**
- selecting cooperation partner by auction
- encouraging other agents to enter

Fig. 4. Aspects of the element "players (agents)" in the game (B/N)

Figure 4 shows the agents in a value net (competitors, complementors, suppliers and customer) and the possibility of changing the cast of agents.

Classically, a competitor is a participant on the same market who decreases the price/demand for the other' products by increasing the value of the own products in the eyes of the customers. As the interests are in general antagonistic, the relationships can be characterized by a "win-lose" situation. "Complementor" is a neologism by B/N that means an agent that has offers that are complementary to the own ones. Complementors offer products/services that increase the value to the product/service of the own enterprise, but they do not compete at the same market. Customers appreciate a product more if they already possess or can get a complementary one. Roughly said, the relationship among complementors is in general "win-win" (the interests go into the same direction). Suppliers and customers are part of the same supply chain. However, in the co-opetition approach they are similar with the complementors in the sense of “win-win”-relationships.

B/N argue that the distinction between “win-win” relationships and “win-lose” relationships is not as clear as it may look on the first sight. An enterprise competes with suppliers, demander and complementors concerning the distribution of the commonly achieved utility (i. e. profit). Thus, negotiations are a competitive situation. On the other hand, there are many possibilities of profiting by coordinating one’s behavior with that of the competitors. Even if the explicit agreements are restricted by law, tacit collusions about prices, products, conditions, etc. (Besanko 2009) are thinkable. Even if there is no direct communication, it can be wise for competitors not to attack each other, and to avoid price wars, etc.: B/N argue that “a satisfied competitor is less dangerous than a distressed one”.

An agent changes the “cast of agent” as soon as it is advantageous, by quitting cooperative relationships or finding new cooperation partners. Auctions are an important procedure to select new cooperation partners. In this paper, the agents that have the possibility to enter the game are termed "potential agents”.

Added value

<u>**Added value**</u>:
- **Profit for oneself:** by own participation or by others’ participation
- **Profit for other agents by one’s own participation:**
  - Is it good or bad for oneself, if other agents’ added value increases?
  - “win-win” vs. “win-lose” situations

Fig. 5. Aspects of the element “added value” in the game (B/N)

Added Value (figure 5) refers to the value difference between the participation (or existence) and the non-participation (or non-existence) of an agent, product, etc. in the game.

An agent thinks about the maximization of his own profit. However in order to achieve this, he has to think not only about the effect of his own participation in the game but also about the effect of the other agents’ participation. Additionally, he has to understand whether it is advantageous to bring added value to other agents, e. g. in order to increase suppliers’ or customers’ loyalty, etc. (“win-win”).

It is dangerous to try to increase one’s own profit at the cost of another agent (opposite of added value), due to the possibility of retaliation (“win-lose”). The scheme coincides with the classical prisoner’s dilemma:
“win-lose”, “lose-win” → “lose-lose”.

Rules

Rules:
▪**Distinction between:**
- rules determined by the government
- rules determined by the culture
- rules for the treatment of mass market
- rules for individual relationships

▪**"Which rules will rule?"**
- own possibilities of changing rules
- others' possibilities of changing rules

Fig. 6. Aspects of the element "rules" in the game (B/N)

Rules (figure 6) are principles that govern social behavior and restrictions. They define the way a game or sport, etc. has to be conducted, or how to behave in business, traffic, etc. B/N explain rules as follows: "most of the rules businesspeople play by are well-established laws and customs. They have evolved to help ensure that trading practices are fair, that markets keep operating, and that contracts are honored. To step outside these rules would be to risk legal penalties or exclusion from the markets".

B/N distinguish between:

- governmental or official rules,
- cultural rules,
- rules in the relationships between business agents.

In the relationship between business agents, B/N distinguish between:

- mass markets and
- individual relationships and explain, how rules can be influenced advantageously. Thus an agent has to recognize which rules are advantageous, which ones are of disadvantage and what are the possibilities to change them.

It is the question which rules will rule. In individual relationships negotiations are usually the prerequisite for cooperation. In the relationship towards a mass market, negotiations are often not possible. The supplier usually determines the rules unilaterally and customers usually do not have many possibilities to influence them. The governmental and cultural rules are termed by Brandenburger and Nalebuff "meta-rules". They can be regarded as externally given. Nevertheless there is the possibility of influencing laws by lobbying, etc.

"Tactics"

"Tactics" (refers to negotiations):
▪How do others perceive the game/negotiation?
▪Should the game be transparent or opaque?
▪Which perceptions should be preserved or changed?
▪Is there enough reliance or is a mediator needed?

Fig. 7. Aspects of the element "tactics" (refers to negotiations) in the game (B/N)

The word tactics (figure 7) is presumably misleading because it refers to how to control the perceptions by other agents in negotiations. B/N say: "Games in business are played in a fog". This means that the agents usually are confronted with the problem of incomplete information. "The job of managing and shaping competitors' perceptions is an essential part of business strategy. Perceptions play a central role in negotiations. The domain of perceptions is universal".

The agents have to decide in general whether the game should be played transparently or opaquely. Each agent should recognize which perceptions by other agents should be preserved and which should be changed. However it is difficult to achieve such an "information control" over other agents where uncertainty is built up (e. g. by bluffing), preserved or reduced.

Negotiations typically take place in a fog. Negotiators try to show and hide information deliberately in order to improve their position. However this is challenging because basically everything sends signals. Without sufficient reliance among the agents, negotiations are likely to fail. This can be solved by a negotiator that is accepted by both sides.

Scope, boundaries

Scope, boundaries:
▪What is the current scope or boundary of the game?
▪Should it be changed?
▪Should the game be linked with other games, e.g. by
- market entries?
- longer-term contracts?

Fig. 8. Aspects of the element "scope" in the game (B/N)

The scope (figure 8) or the boundaries of a game are defined artificially. All games are connected with each other. Even if the separation of games is convenient for analysis, it must not be neglected that decisions might have unexpected impacts on any other issues. The complete game comprehends the whole world, but a model can only depict a small excerpt limited by region, time, technology, etc.

The agent should ask himself, whether to link/delink one game with/from another one e. g. by entering new markets or making longer-term contracts. If a new agent wants to enter a market, he should try to avoid competition. This can be done by occupying a price segment that is not that interesting for the incumbent(s), or bringing new products with the chance of failing. Particularly in businesses, where technology advances quickly, market superiority is deceptive. New agents may emerge with superior technology and the core competency of the incumbent in one technology may turn out as rigidness in another technology.

Time is a crucial determinant for the scope of the game. Longer-term contracts assure the links between games of different periods and therefore can be a prerequisite to protect added value. On the other hand, longer-term contracts can be difficult to assert due to changing agents, changing added value, external rules and perceptions.

Analysis of B/N's "Co-opetition"

B/N's "co-opetition" approach is an important step towards a practice oriented business theory in the spirit of game theory. It is a comprehensive attempt to make highly abstract or mathematic concepts in economics applicable. There is no other comparable concept yet that focuses on the ambivalence of competition and cooperation in each business relationship. Nevertheless, B/N's co-opetition has some fundamental flaws, like that:

- the foundation in the economic sciences is not explained,
- the internal structure that is disputable and as it is targeted to a non-professional readership.

The only economic theory that is mentioned is the game theory. However it is not clear in which way game theory is used and whether there are other theories that are in connection with the co–opetition approach.

The "elements" "players" (agents), "added value", "rules", "tactics", "scope" (PARTS) are not in a logical structure. The short-cut "PARTS" seems to be based on the intention of being memorable and easily accessible for a large readership. It is misguided from the point of view of priorities and the kind of chosen criteria. In order to show the structural problem, table 2 lists some important aspects that refer to two or more "elements" of "PARTS", so that the "elements" overlap:

Table 2. Overlaps of elements, x marks the reference in B/N's book "Co-opetition" (by the author)

Aspects by B/N	Overlap of elements:	P	A	R	T	S
1	Value net: determination of agents	x			x	x
2	Value net: distinction between mass markets and individual agents	x		x	x	x
3	Value net: "potential agents" and their impact	x	x		x	x
4	Value net: "win-win" vs. "win-lose" relationships	x	x			
5	Negotiations: restricted to relationships with individual agents	x	x	x	x	x

1. The determination of agents concerns also the "scope" of the game. By each additional agent, the complexity of the game increases tremendously (Pin 2005). Furthermore the cast of agents is the result of negotiations, so that the determination of agents also refers to "tactics".
2. The distinction between customers that are
   - individual agents and those that are
   - mass markets (aggregated agents) is introduced at the element "rules". However, the distinction between individual and aggregated agents could also be covered by the element "players" (agents), and therefore also by "scope".
3. Agents who have the potential to enter the game ("potential agents") can be regarded as strategically very important. If an enterprise has a supplier and obtains an alternative, this has crucial impact on negotiation power as it decreases the actual supplier's "added value".
4. "Win-lose" relationships are among competitors and "win-win" among the others relationships in the value net. They are introduced in "agents". However, both "win" and "lose" refer to the "added value".
5. Negotiations (chapter "tactics") can have impact on each element, as "you can negotiate anything" (Cohen 1982). However B/N omit to mention that negotiations are restricted to individual agents and it is not possible to "negotiate" with mass markets. The distinction between mass markets and individual agents is introduced in the chapter "rules", but is ignored it the chapter "tactics".

Hence, though B/N's proposal of the co-opetition theory can be regarded as a good starting point for research, it is not implementable in the given form.

1.3.2.2. An overview of the literature contributions to the co-opetition theory

The term “co-opetition” has been coined long time before B/N’s book without receiving public attention. Already in 1911, Kirk S. Pickett of the oyster manufacturer “Sealshipt” coined the word “co-opetition” in order to describe the relationships among his 35,000 oyster dealer by stating: “You are only one of several dealers selling our oysters in your city. But you are not in competition with one another. You are co-operating with one another to develop more business for each of you. You are in co–opetition, not in competition”. T. Cherington referred in his book “Advertising as a business force” from 1913 (Cherington 1976) to this first mention. The Californian historian R. Hunt reintroduced “co-opetition” in the Los Angeles Times (1937). However, none of these early introductions received any public attention. For more than half a century there has not been any approved publication that uses this word. Ray Noorda, the long-time CEO of Novell Corporation, is regarded as the person who reintroduced the term co-opetition into public debate in 1992 (Fisher 1992).

However the major impulse has been given by B/N (1996), though it is written in a non-scientific style. Afterwards, a multitude of literature contributions has followed and refers to both highly theoretical questions and to certain industries.

Afuah (2000) takes a look at business networks that undergo fast technological changes. Due to these changes, enterprises possibly lose their competitive advantage, because their technology becomes obsolete. Furthermore the old skills and organizational routines can handicap or delay the adaption to the changed situation. However, if marketing capabilities are important, difficult to imitate and still intact, the enterprise can assert its position in the network. In this case, enterprises suffer under the action of other enterprises that work on increasing the technological level, however still offer marketing cooperation, which is an example for “co-opetition”.

Afuah also describes another important issue connected with network effects, the phenomenon that each additional network member increases the utility of each other member. If standards and network effects are important in an industry, an enterprise may look for alliance partners in order to assert a certain standard or design. In this case competitors benefit from each other by using the same technological standards or making their standards compatible.

Levy and Loebbecke (2001) propose a framework for inter-organizational knowledge sharing with ambivalence of competition and cooperation. Cooperation leads to the problem that knowledge that has been transferred can be misused at a later point of time. Therefore they develop a guideline with controlling procedures for the management in order to show how to prevent uncontrolled knowledge transfer.

Bagshaw and Bagshaw (2001) provide a case study, where a management consultancy, a business school and an outdoor activities provider establish a joint enterprise as a common project. Their different points of view can be considered as competing with each other. However the project benefits of the teamwork and the variety of influences. The joint enterprise is characterized by both competition and cooperation and as a representative example for an application of the co-opetition approach.

Dagnino and Padula (2002) give a comprehensive introduction into the theoretical research on the field of co-opetition. They argue that co-opetition is a field that has not been researched sufficiently due to limited or non-existing theoretical foundations. In order to propose a foundation, they compare it on the one side with the mainly competitive perspective and the mainly cooperative perspective. The competitive perspective is represented by Porter and particularly his seminal book "Competitive Strategy" (1980) and by Williamson and his major contributions on the field of "transaction cost economics" (1975, 1985). On the other side, the cooperative perspective is shown by Contractor and Lorange (1988), who emphasize strongly on the benefits of cooperation and regard them as sufficient incentive to be not seduced by possible benefits of opportunism.

Co-opetition is described by Dagnino and Padula as a new perspective that emphasizes on the "partial or incomplete congruence" of interests and goals of enterprises if they are interdependent. It is regarded as an integrative theoretical bridge between the competitive and the cooperative perspective that intends to "rebalance" the respective biases, in order to generate an enhanced understanding of sustained business performance. Dagnino and Padula propose a "theoretical framework (that is) underlying the co-opetitive perspective":

1. "Firms' interdependence is both a source of economic value creation and a place for economic value sharing".
2. "Firms' interdependence is based on a variable-positive-sum game which may bring to mutual but not necessarily fair benefits to the partners because of several competitive pressures of different nature that may undermine their co-opetitive structure".
3. In a variable-sum game structure, firm interdependence is based on "partially convergent interfirm interests".

Song (2003) explains the significance of co-opetition in the port industry with the rationalization efforts of the preceding decade. Many port operators who previously ran only their local business now extend their business to the regional or global scale. This becomes possible by cooperating with competitors in order to reach the critical mass. Song presents as example the ports of Hong

Kong and South China. As the ports remain independent, they are competitors despite of cooperation.

Zineldin (2004) recommends to strategy and marketing planners in organizations to consider potential benefits of collaboration and coordination with the competitors. He claims that "co-opetitive partnerships" are an effective response to environmental threats and opportunities. He shows possible preconditions for the survival of a "co-opetitive partnership" and compares it with a marriage. The participants get to know each other and make a "ceremony", the signing of the business contract. Conflicts that can arise must be coped with clear and agreed mechanisms. However, divorce is always possible.

Luo presents in his book "Coopetition in international business" (2004) various issues of business relationships between different countries. He regards co-opetition is a "loosely coupled system in which agents maintain certain interdependence without loosing their organizational separateness". Luo's typology of co–opetition is shown in table 3:

Table 3. Luo's (2004) typology of co-opetition in dependence of the intensity of competition and cooperation

		Cooperation	
		Low	high
Competition	high	Contender: Bargain, challenge, appeasement	Co–opetitor: compromise, influence
	low	Alienator: compliance, circumvention	Partner: accommodation, co–optation, adaptation

He investigates

- "co-opetition with global rivals",
- "co-opetition with foreign governments" or the
- co-opetition within one multinational enterprise.

He recognizes a simultaneous increase of competitive pressure and desire for cooperation between multinational enterprises (MNE). Cooperation with a given rival can facilitate knowledge acquirement, technological progress. In the context of product innovation or the product introduction in foreign countries it can reduce costs, risks and uncertainties. In many cases it is too costly or not possible because of laws for an enterprise to enter a foreign market. In these cases, cooperation even with a competitor might be inevitable. Luo recommends "co-opetition groups", where the collective power of the "global players" (globally active agents) is solidified towards "outside stakeholders" like home and host governments. Concurrently the “competition” helps to dilute anti-trust regulations or anti-monopoly demands.

Luo delves into the relationship between MNEs and foreign governments and the interdependence in many aspects like resource sharing, market expansion and economic growth. It is the interest of the MNEs to succeed in the market while government institutions are “controllers, regulators, clients or adjudicators of private-sector activities. On the other side, governments are (should be) interested in “maximizing social welfare, which is contingent on efficiency, equity and social considerations”.

Luo develops ideas referring to co–opetition of dispersed subunits within a multinational enterprise. He argues that these subunits in different countries are interdependent in the sharing of resources and knowledge and in the rationalization of the value chains. Concurrently they compete for the support by the corporation, resources, etc. He classifies enterprise subunits “aggressive demander”, “silent implementor”, “ardent contributor” and “network captain”.

Ren and Shi (2005) expressed the idea that reliance among cooperating agents determines the degree of cooperation and depends on long period mutual benefit. That is a comprehensible approach in the modelling of reliance development.

Luo (2006) regards the ambivalence of competition and cooperation of enterprises that interact on global scale. He introduces four situations that describe the kind and degree of co-opetition: contending, isolating, partnering and adapting. Depending on the numbers of global rivals and international markets, guidelines for relationship building are developed that include dispersing, concentrating, connecting, and networking, etc.

Gurnani (Gurnani et al. 2006) focuses on supply chain management. In a supply chain one enterprise refines or markets a product that another enterprise has produced. In order to increase the customers’ demands, an enterprise has to make investments into quality or the reduction of prices. This can be exploited by the cooperation partner that sees the possibility of suspending own investments and therefore acts as a free-rider. The authors propose buy-back agreements, quantity and quality commitments and information sharing as countermeasures.

Gnywali (Gnywali et al. 2006) delves into the advantages and disadvantages of certain positions in networks. Networks are regarded as aggregations of bilateral links. Enterprises that have more links tend to be more influential and autonomous. These links can also refer only to particular issues. For instance, enterprises that cooperate in research & development possibly compete in marketing. 3 types of flows in supply chains are recognized: information, assets and status. “3 primary levels of analysis” are determined:

- the industry level, where "patterns" of competitive and cooperative activities across different industries are analysed,
- the group level that refers to "competitive groups",
- the firm level where an individual firm's competitive and cooperative behaviour is regarded.

Chen and Fan (2006) analyse the stability of strategic alliances. They try to find stable solutions by employing game theory in an attempt to develop a theoretical basis for strategic alliances. They argue that unplanned changes from the perspective of one or more partners lead to alliance instabilities, as soon as the bargaining power shifts. Furthermore, unrealistic goal planning, imperfect implementation or goal dissimilarities of the partners make strategic alliances in general not stable. However, alliances can bring an advantageous strategic competitive position against the competitors (Porter 1985). Chen and Fan also refer to the transaction costs economics (Williamson 1985) that emphasizes the negative effect of opportunistic behaviour in the relationships between business partners.

Schulze and Spiller (2006) investigate the trust between suppliers and buyers in the German pork industry. By making a comprehensive survey over 357 pork producing farmers, they recognize a lack of trust in the relationships towards the processors in the meat industry. They develop a "measurement concept of trust", where factors that determine trust are developed like management competence, enterprise performance, goal compatibility, communication and opportunism.

López-Gómez and Molina-Meyer (2007) build a bridge to population dynamics. They claim that "partial cooperation" or an interaction with competitive and cooperative aspects can lead to an explosive increment of productivity, creativity, diversity and efficiency after an appropriate time span. On the other hand, the attempt to evade competition can lead to segregation mechanisms where enterprises adapt to specific markets with their properties and regulations and use spatial heterogeneities, i.e. market boundaries that are caused by distance. Thus, business networks are described as analogous to ecological systems.

Sierra and Debenham (2007) develop a negotiation model by defining the five dimensions legitimacy, options, goals, independence and commitment and combining it to the catchy word "LOGIC". They give the advice to negotiators to prepare by analysing their positions regarding these dimensions. Additionally they introduce two "primitive concepts": intimacy as degree of closeness and balance as degree of fairness.

Cheng (Cheng et al. 2008) takes a look at "trust and knowledge sharing in green supply chains". The inter-organizational knowledge sharing is investigated on 288 major "green" manufacturing firms in Taiwan. "Green" symbolizes strong effort to consider environment protection in the production. The majority of the firms is in the industries of electronic components, machinery and chemistry. They recognize "shared values", "participation", "communication", "learning capacity", "opportunistic behaviour" and "resource fitness" as the determinants for trust and in consequence for inter-organizational knowledge sharing.

Montgomery (2008) recommends to CEO's to contemplate more carefully about enterprise strategy. The strategy depends on the aims of the enterprise. The aims must be "created and re-created for a company's continued existence". It does not matter how compelling or how clearly defined a strategy is. As circumstances change, the strategy must be checked and updated permanently. Like contracts, the strategy cannot be determined completely. Therefore strategy is a dynamic process and the job of a strategist never ends.

Bojar and Drelichowski (2008) investigate the development of enterprises in the agricultural industry in many EU member countries, there under Lithuania, Poland and Czech Republic. Despite of the fact that agricultural companies are competitors, they have various common interests like building up the infrastructure for production on high quantitative scale, general development of their rural areas and therefore the obtainment of financial support by the EU. The attempt to increase the common market power compared with other competitors or in front of customers is a characteristic of the co-opetition approach. Thus, this paper is thematically close to that of Song (2003).

Another contribution to supply chain management comes from Bakshi and Kleindorfer (2008). They develop the special case where two agents are connected by a common threat, for instance terrorist attacks or natural hazards. They try to form contracts to share the risks and losses or to share relevant information. A bargaining model is proposed where a demander and a supplier intend to make a contract. However the demander suspects the potential supplier of exploiting the situation of insecurity and waiting for a possibility to cheat. This refers to the concept of "moral hazard" in the new institutional economics (Göbel 2002). Therefore the demander plans to give an incentive to the potential supplier to refrain from committing fraud.

Ngo and Okura (2008) investigate privatization and its impact on the level of competition and cooperation in a mixed duopoly market, where a semi-public and a private firm meet at a market. They show that the semi-public company is more concerned about public welfare. The private company exploits that as a free-rider. The existence of public or semi-public enterprises has positive effects on the surrounding business networks.

Hu (Hu et al. 2008) proposes an evolutionary model of supply chains (similar to López-Gómez' and Molina-Meyer's model of population dynamics of 2007). They compare business networks with many agents, where strictly competitive and strictly cooperative strategies prevail concurrently. They show that out of the competitive environment rather a situation evolves that is in the middle between competition and cooperation and provides the best profit perspectives in the whole system. Hence, in the long run a competitive outset is recognized as advantageous for the whole system in comparison with a totally cooperative outset.

Eriksson (2008) recognizes the problem in the Swedish construction industry that contract partners do not have sufficient reliance to behave cooperatively. In a survey of 87 Swedish construction companies he claims to have recognized that mistrust prevents cooperation in the way how the transaction cost theory would predict it. His aim is to demonstrate the companies how to make unbiased and systematic procurement decisions.

Baumard (2008) gives a comprehensive overview over “learning strategies in coopetitive environments”. “Correct or cooperative behaviour is listed like generosity, contrition, signalling of good faith, signalling of conventions, etc. These determine the “ambiguities and tensions of paradoxical simultaneous cooperation and competition”. Baumard proposes a typology of “learning strategies”. For instance he understands the TIT-FOR-TAT principle (Axelrod 1984) as “reciprocal symmetric transparent learning” or the adverse selection (Akerlof 1970; Spence 1973) as “asymmetric open adverse learning”.

Guan (Guan et al. 2009) investigates wireless multimedia transmissions for many users and the optimal and fair resource allocation. They build a formal model where they understand the numerical results as evidence that co-opetition strategies are a good way to adapt to the changes of network conditions or participating users and help to achieve better quality of service (QoS), etc.

Sun (Sun et al. 2009) delves into evolutionary game theory as well, in order to find an “effective co-opetition mechanism of partners within high quality pork supply chain”. They claim that their model provides 8 factors that influence co-opetition: cooperation costs, cooperation income, “coefficient of income distribution”, decrease of cooperative risk, “coefficient of risk compensation”, probability of risk, management scale and “coefficients of either encouragement or punishment”.

Roy and Yami (2009) investigate innovation in an oligopolistic context where one firm is dominant and the other ones follow. Therefore the introduction of multiplex movie theatres in France has been investigated. It is shown that in spite of the obvious competition among the multiplex theatre companies, cooperation plays an important role as well, for instance because of common infrastructure or movie provision, advertising, more acceptance among the audience, etc.

Gueguen (2009) studies cooperative behavior of companies in the information technology industry. He shows the importance of establishing technological standards and therefore the necessity for competitors to cooperate. As example, the five “major business ecosystems” of mobile operating systems are compared:

Palm, Microsoft, Symbian, Research in Motion (RIM) and Linux. Gueguen highlights the relationships between and within the "business ecosystems". The possibilities are shown of how key agents of rivalling "business ecosystems" can cooperate.

Schoo (2009) describes the "Ambient Networks Project" that has been implemented 2004–2007 by a consortium of more than 40 companies, among them industrial enterprises, network operators and academic institutions like the Fraunhofer Institute Munich, Vodaphone, Nokia-Siemens, Ericsson, the Technical University Berlin, etc. The project addressed the future generation of mobile communication systems for voice and data transmission, 4G (4th generation). A framework has been developed that might allow companies to enter the market with low structural barriers. This is planned to be achieved by the development and provision of a comprehensive technological platform that regards authorization, availability and security aspects, and is therefore the basis for the provision of access (availability), applications, contents, etc. Companies that enter this industry and do not have explicit bilateral agreements can collaborate through the utilization of "pre-shared keys", etc.

1.3.2.3. Classification of the co-opetition related literature

The co-opetition related literature is classified according to certain criteria, in order to assess the respective usability for further research. The first classification criteria refer to the kind of contribution (Stein 2010b):

- Contribution to the theoretical foundation and structure of the co-opetition approach,
- Contribution to special theoretical problems, like technological progress, the assertion of industrial standards, etc.
- Contribution to a problem solution in a particular industry or supply chain, like the sea ports in Eastern Asia, the agriculture in Eastern Europe, mobile communication, etc.

There is the special case of models that use approaches of evolutionary game theory or the related field of population dynamics (Maynard-Smith 1982). Though it is a promising field, it is excluded from the analysis, as it uses models with a high number of individuals and has been barely deployed in economics yet. In table 4, the publications that refer to evolutionary game theory are marked with an asterisk (*).

The next classification criteria refer to the use of mathematics:

- Game theory or
- Mathematics aside from game theory.

The criteria are weighted according to their importance referring the finding of the frame of co-opetition research. The lowest weight value is 1 and the highest one is 4. The theoretical foundation and structure is the major field of research. Therefore these contributions are weighted with “4”. The contributions to special theoretic problems gain relevance, as soon as there is an accepted theoretical foundation. It is weighted here with “1”. It is generally important that the relevance of co-opetition for problems in particular industries or supply chains is shown. Therefore it is weighted with “2”. As co-opetition is considered to become an applicable business theory in the spirit of game theory, the game theory that is used in the publication is weighted with “2”. All mathematics aside of game theory is weighted with “1”.

Table 4 shows all criteria with their weights. Each publication is evaluated for each criterion with 1 to 3 points. The points are multiplied with the weights from table 4 and are summarized, which is shown in table 5.

Table 4. Weights of the co-opetition evaluation criteria (by the author)

Criterion	Weight
Contribution to the theoretical foundation and structure	4
Contribution to a special theoretic problem	1
Contribution to problem solution in a particular industry supply chain	2
Use of game theory	2
Use of mathematics aside of game theory	1

Table 5 shows that the emphasis of many publications is on the treatment of special theoretical problems. The solution of problems in connection with particular industries is less treated. In comparison, the question of the theoretical foundation and structure is neglected.

Table 5. An overview of publications related to co-opetition with estimation of their importance (by the author)

	Author	**Year**	**Issue**	**S**	**T**	**I**	**G**	**M**		**Sum**
			Weights of table 3:	**4**	**1**	**2**	**2**	**1**		
	Competitive perspective:									
1	Schelling	1960	Game theory: strategy of conflict							
2	Jensen	1976	Institutions: principal-agent theory							
3	Porter	1980	Competitive Strategy: neoclassical competition and profit maximization							
4	Williamson	1985	Institutions: transaction cost economics							

Continuation of **Table 5**

5	Contractor/Lorange	1988	Advantages of cooperation							
7	Hunt	1937	Claim to unify competition and cooperation	1	0	0	0	0		**4**
8	Fischer	1992	IT company Novel's business philosophy	0	0	1	0	0		**2**
9	**Brandenburger, Nalebuff**	**1996**	**"PARTS" model, value net, small case studies (book)**	**1**	**2**	**3**	**1**	**0**		**14**
10	Afuah	2000	Business networks/ technological changes	0	3	0	0	1		**4**
11	Levy, Loebbecke	2001	Knowledge sharing	0	3	0	1	0		**5**
12	Bagshaw, Bagshaw	2001	Case study: outdoor activity provider	0	1	2	1	0		**7**
13	**Dagnino, Padula**	**2002**	**Incomplete "interest congruence", change of perspectives: co-opetitive instead of purely competitive or cooperative**	**3**	**1**	**0**	**1**	**0**		**15**
14	Song	2003	Sea port industry	0	1	2	1	0		**7**
15	Zineldin	2004	Co-opetitive partnerships	1	0	0	1	0		**6**
16	**Luo**	**2004**	**Multinational enterprises and co-opetition**	**1**	**3**	**1**	**2**	**0**		**13**
17	Ren, Shi	2005	Reliance determining cooperation level	1	1	0	2	2		**11**
18	Luo	2006	Global scale co-opetition	1	2	0	1	0		**8**
19	Gurnani, Erkoc, Luo	2006	Free riders at supply chain investments	1	3	0	1	3		**12**
20	Gnywali, He	2006	Properties of certain network positions	1	2	1	1	2		**12**
21	Chen, Fan	2006	Stability of strategic alliances, repeat. games	1	0	0	2	2		**10**
22	Schulze, Spiller	2006	German pork industry	0	1	3	0	1		**8**
23	López-Gómez	2007	Partial cooperation with population dynamics*	1	2	0	1	3		**11**
24	Sierra, Debenham	2007	Negotiation model "LOGIC"	1	3	0	1	2		**11**
25	Cheng, Yeh, Tu	2008	Knowledge sharing in Taiwanese industries	0	2	3	0	1		**9**
26	Montgom.	2008	Advice for CEOs to focus more on strategy	1	0	0	0	0		**4**
27	Baumard	2008	Learning strategies	1	2	0	2	1		**11**
28	Bojar	2008	Agriculture in Lithuania, Poland, Czech Rep.	0	0	3	0	0		**6**
29	**Bakshi, Kleindorfer**	**2008**	**Bargaining with incomplete information in supply chains**	1	3	0	2	3		**14**
30	De Ngo, Okura	2008	Duopoly: private and semi-public enterprise	1	2	0	2	2		**12**
31	Hu, Houdet	2008	"Evolutionary" supply chain, many agents*	0	3	0	2	3		**10**
32	Eriksson	2008	Swedish construction industry	0	2	3	1	0		**10**

Continuation of **Table 5**

33	Guan, Yuan	2009	Wireless multimedia transmissions	0	3	2	1	3		**12**
34	Sun, Zhang, Lin	2009	Evolutionary game, pork supply chain*	0	2	1	1	3		**9**
35	Roy, Yami	2009	Innovation in oligopolies, cinemas in france	0	1	2	0	0		**5**
36	Gueguen	2009	Mobile operating systems	0	1	3	0	0		**7**
37	Schoo	2009	"Ambient networks", mobile communication	0	2	3	0	1		**9**

Legend:

*	use of evolutionary game theory
S	Contribution to the theoretical foundation and structure
T	Contribution to a special theoretic problem
I	Contribution to problem solution in a particular industry or supply chain
G	Use of game theory
M	Use of mathematics except of game theory

Most important publications: 13, 9, 29, 16

1.4. Game theory as instrument for the mathematical formalization of co-opetition models

The object of game theory (Holler 2000; Podvezko 2008) is the analysis of strategic decision situations, i. e. of situations in which the result depends on the decisions of more than one decider in a way that the result cannot be determined independently from the decisions of the others. It is a normative economic theory where the agent is led to an optimal decision. He is aware of the interdependency and all consequences of all decisions, and tries to act in the best possible manner, in order to pursue his personal interests. Interest conflicts and allocation problems are the typical issues. Game theory provides a language with abstract and formal instruments for the analysis and understanding of such situations.

In the more restrictive definition i. e. by Holler (2000), each agent is aware of the agents' interdependency and each one anticipates that all other agents are aware of that interdependency as well. However many approaches violate this narrow definition. In figure 9 the structure of the main fields of game theory is depicted.

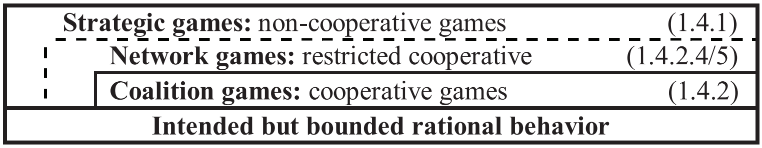


Fig. 9. Structure of main fields of game theory

The preceding definition claims that the agent or in the strict case all agents are in accordance with the ideal of the rational decider (“homo economicus”). However due to:

- the complexity of decisions,
- cognitive restrictions or the of lack of contemplation or
- incomplete information,
- humans’ rationality is bounded. That is why in modern game theory the rationality postulate is weakened to “intended but bounded rationality” (Simon 1994; Rubinstein 1998).

In the “strategic games” (or non-cooperative games) agents’ strategies are explicitly analyzed. “Coalition games“ (or cooperative games) delve into the problems of influence and dominance in cooperation relationships that are based on mutual agreements. “Network games” (or restricted cooperative games) are the newest direction of game theory and a generalization of coalition games. Situations where communication is restricted can be analyzed. Despite of the different formalizations, the fields of game theory are very close to each other. Coalition games are a special case of network games and only have a separate formalization due to historical reasons. The strategic games seem to be separated very strongly (due to formalization), but each coalition or network game has an implicit strategic game. If agreements are not binding (or the costs of breaking the agreement are low), the concepts of coalition and network games are in general not relevant.

1.4.1. Strategic game theory

Strategic game theory is also called non-cooperative game theory. Though all fields of game theory are at least implicitly strategic, the non-cooperative game theory has its own formalization. Figure 10 gives an overview over the fields of strategic games that might be relevant for co-opetition:

Strategy:
complete determination of actions for all situations based on available information

Strategies and strategic games (1.4.1.1.)
- Information Depicted as matrices ar tree diagram
- Function information →action

Nash-equilibria and refinements (1.4.1.2.)
- Nash-equilibrium: assumption of all agents' rationality
  Stochastic games: mixed strategies or assumed determinism as simplification
  Sequential games: backward induction
- Dominant equilibrium: no assumption about other agents' rationality

Backward induction in sequential and dynamic games (1.4.1.3.)

Oligopolies between Cournot-Nash-equilibria and cartel solutions (1.4.1.4.)

TIT-FOR-TAT: unintended cooperation in repeated market games (1.4.1.5.)

Network (special case: coalition) formation (1.4.1.6.)
- (Component-) Pareto-efficient Nash-equilibria:
  Coalition-proof Nash-equilibria
  Strong Nash-equilibria
- Approval of coalition/network formation:
  Coalitions: by all participating agents
  Networks: by pairs of agents

Fig. 10. Overview over the fields of strategic game theory that may be relevant for co-opetition

1.4.1.1. Strategies and strategic games

The strategy of agent i, S_i is in the sense of game theory a function of the information set (all available information) H_i on the action set A_i, which delivers the optimal decision or sequence of decisions. Hence a strategy is defined as (Vega-Redondo 2003):

$$s_i : H_I \to A_I \text{ with } \forall h \in H, \text{and } s_i(h) \in A(h) \quad (2.1)$$

The information is depicted in matrices or a tree diagram with knots and relations. A strategy considers all possible outcomes for all thinkable situations, even if the probability of occurrence is expected as extremely low. All information has to be considered and an agent who intends to play rationally constructs a stringent decision model.

A strategic game is a 3-tuple consisting of the players N, the set of all possible strategy decisions S_i and all possible outcomes π_i (Vega-Redondo 2003):

$$SG = \left\{N, \{S_i\}_{i=0}^{n}, \{\pi_i\}_{i=1}^{n}\right\} \text{ with } s_i \in S_i \tag{2.2}$$

1.4.1.2. Nash-equilibria, dominant equilibria and randomization of strategies

The Nash-equilibrium is a solution that has proven to be a fundamental concept in strategic games in order to find the right strategy. It results from the mutual anticipation that all other agents deploy optimal strategies and the rationality of all agents is "common knowledge". In the Nash equilibrium no agent has an incentive to deviate. The strategy choice is optimal because no agent can achieve higher outcome by deviating in consideration of the rational decisions of the other agents. Therefore the following infinite chain of statements is valid:

- every agent acts rationally,
- every agent knows that every agent acts rationally,
- every agent knows that every agent knows that every agent acts rationally,
- every agent …, etc.

A reaction function defines the assumed reaction of one agent on the assumed action of the other agents. The Nash-equilibrium is a fixed point of (set-valued) reaction functions formulated by Kukitani (1941). A fixed point is the intersection of a function with the identity $f(x) = x$ Therefore, if the argument of a reaction function is a Nash-equilibrium the result is the same Nash-equilibrium. *-i* are the respective other agents from the perspective of *i*. Each agent selects an optimal strategy s_i^* given the optimal strategies of all other agents s_{-i}. For agent i the following must be fulfilled:

$$u_i\left(s_i^*, s_{-i}^*\right) \geq u_i\left(s_i, s_{-i}^*\right) \;\; \forall s_i, s_{-i} \in S_i \tag{2.3}$$

In the case of incomplete information it is not clear how the other agents intend to decide or how external event are going to take place. It is possible to base the decision on a lottery with weighted alternatives, the "mixed strategies" (Harsanyi 1967). Another way is to assume determinism as simplification, which is done in the thesis.

The concept of dominant equilibria as the result of the iterated elimination of dominated strategies is very similar to the determination of the Nash-equilibrium. However the strict assumption that all other agents act rationally is dropped. Thus dominant equilibria are particularly relevant in games with bounded rationality. If an alternative is always disadvantageous independently to the decisions of the others, it is crossed off the list. The iteration is continued in the residual game. Thus for agent *i* and the respective other agents *i* the following is valid:

$$u_i\left(s_i^*, s_{-i}\right) \geq u_i\left(s_i, s_{-i}\right) \;\; \forall s_i, s_{-i} \in S_i \tag{2.4}$$

The results of the iteration are always Nash-equilibria but are rarer due to higher requirement (Harsanyi 1988), as shown in figure 11.

Nash-equilibria:
- Assumption that all other agents act rationally

Dominant equilibria:
- Result of iterated elimination of Pareto-dominated strategies
- No rationality assumption about other agents

Fig. 11. Nash-equilibria and dominant equilibria as subset

Therefore dominant equilibria are a subset of Nash-equilibria.

1.4.1.3. Backward induction in sequential and dynamic games

In a sequential game the agents face multi-stage decisions. Dynamic games are a special case of sequential games. At each stage the respective strategy is dependent on the information set about the future and the previous steps of the other agents. Sequential games are depicted in the form of a game tree. Important applications are:

- games with time dimension,
- games with more than two agents or imperfect nature information (Harsanyi 1967), when one agent has to wait for the decisions of others.

Then the Nash–equilibrium is determined by backward induction (BI). That means that the sequential game is fragmented into sub-games and the equilibria are initially determined for the chronologically last sub-games. Stepwise the equilibria are identified for the preceding steps until all sub-games are included. The resulting optimal strategy path is the Nash equilibrium. Figure 12 shows the backward induction in the cases of

- 1 mass market and 1 supplier,
- 1 mass market and 2 unconnected suppliers and

– 1 mass market and 2 connected suppliers.

In the case of 2 unconnected suppliers, it is the classical distinction (Besanko 2009) between

– quantity competition (Cournot 1838) and
– price competition (Bertrand 1883).

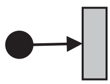
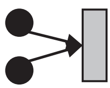
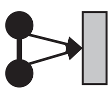
Network	**Backward induction**
 S	The unique supplier anticipates each possible decision of the demander and makes his decision based on that.
 S M	The suppliers cannot make agreements among each other or they cannot benefit from them, what is equivalent. Both suppliers anticipate each possible decision of the demander and make their decisions based on that. This may be in accordance to both the Cournot-Nash-equilibrium that refers to quantity competition (Cournot 1838) and the Bertrand-Nash-equilibrium (Bertrand 1883) that refers to price competition.
 S M	The suppliers can benefit from cooperating and are therefore potential complementors. Both suppliers anticipate all possible decisions of the demander and mutually compare the benefit of the other's cooperation. If it is beneficial to cooperate, the suppliers may form a cartel.
Suppliers: S	Mass markets: M

Fig. 12. Backward induction with 1 supplier, 2 unconnected suppliers and 2 connected suppliers that make their decisions based on the anticipation of the mass markets reaction (Cournot 1838, Bertrand 1883)

1.4.1.4. Oligopolies between Cournot-Nash-equilibria and cartel solutions

In games where 2 or more suppliers supply a mass market, both suppliers anticipate the markets' reaction. Decisions can be made as mutually best reactions, i.e. Nash-equilibria or on the basis of agreements, i. e. cartels. The difference between these both alternatives is the "added value of the cartel".

Cournot-Nash-Equilibria

Quantity decisions are made by the concurrent maximizations of the profit functions. There are "profit functions" which describe continuously the possible profits of an agent in dependence of the decisions of the other agents, assuming that all agents decide rationally. The profit functions are basically calculated by the multiplication of the price with the quantity, where the price depends on the "demand function", which includes the other agents' decisions and the variable costs. Possibly afterwards fixed costs are subtracted as well. Profit functions of agents in quantity competition with heterogeneous goods and cost functions are as follows (demand functions are in brackets):

$$\Pi_1(q_1) = (a - q_1 - d * q_2 - c_1) * q_1 - F \quad \Pi_2(q_2) = (a - q_2 - d * q_1 - c_2) * q_2 - F \quad (2.5)$$

These are the relevant variables:
a: boundary market price that leads to a quantity demand of 0;
d: factor representing the effect of a unit that is provided by the competitor on the demand reduction, i. e. the degree of product heterogeneity, between 0 and 1;
c_1: variable costs for S_1 in the provision of 1 unit;
c_2: variable costs for S_2 in the provision of 1 unit;
F: fixed costs that are incurred with the first provided unit;
p: market price, implicit in the demand function.

In the case of high fixed costs the optimization becomes very complex due to the fact that there are several boundaries and therefore boundary solutions.

In the optimal point:

- the market price,
- the quantities of all agents and
- the profits of all agents

must not become lower than zero. Here the boundary solutions are not calculated. It is just checked, whether there are internal solutions for particular parameters. The calculations are as follows:

$$\frac{\delta \Pi_1}{\delta q_1} = a - 2q_1 - d * q_2 - c_1 =: 0 \quad \Leftrightarrow \quad \hat{q}_1 = \frac{a - d * \hat{q}_2 - c_1}{2} \quad (2.6)$$

$$\frac{\delta \Pi_2}{\delta q_2} = a - 2q_2 - d * q_1 - c_2 =: 0 \quad \Leftrightarrow \quad \hat{q}_2 = \frac{a - d * \hat{q}_1 - c_2}{2} \quad (2.7)$$

Cartel solutions

Profit functions of 2 agents in cartel with heterogeneous goods and cost functions (with different cost functions the products have to be heterogeneous, otherwise the supplier with the cheaper production produces everything):

$$\Pi_{cart} = (a-(q_1+d*q_2))*q_1 - c_1*q_1 + (a-(q_2+d*q_1))*q_2 - c_2*q_2 \qquad (2.8)$$

$$\frac{\delta\,\Pi_{cart}}{\delta\, q_1} = a - 2q_1 - 2d*q_2 - c_1 =: 0 \;\Leftrightarrow\; \hat{q}_{1;cart} = \frac{a-2d*\hat{q}_{2;cart}-c_1}{2} \qquad (2.9)$$

$$\frac{\delta\,\Pi_{cart}}{\delta\, q_2} = a - 2q_2 - 2d*q_1 - c_2 =: 0 \;\Leftrightarrow\; \hat{q}_{2;cart} = \frac{a-2d*\hat{q}_{1;cart}-c_2}{2} \qquad (2.10)$$

Obviously, the quantities are smaller in the cartel case ($cart$): $\hat{q}_{1;cart} \prec \hat{q}_1$ and $\hat{q}_{2;cart} \prec \hat{q}_2$ and the market price is higher. This is similar with the monopoly where the profit is higher than in a duopoly, as the demand function is linear. As they cooperate by agreement, the added value can be calculated and is distributed. However it is not a common provision of a product or service so that each agent keeps his own added value. There is not compensation in the sense of Myerson's "axiom of balanced contributions".

Furthermore, cartels are not stable. Each agent has the incentive to deviate unilaterally. For instance, it can be predicted that cartels do not occur in 1-round games, as there is no punishment mechanism.

1.4.1.5. TIT-FOR-TAT: unintended cooperation in repeated market games

Repeated games are a special case of sequential games, where the agents have the same decision problem in each round. In repeated games cooperation is possible that is not explicitly intended. Assuming a mass market with quantity competition, where 2 suppliers decide in each round whether they play competitively or form a cartel. Each agent has the incentive to defect from a cartel agreement, and to raise his own profit at the expense of the other one.

However, in the successive rounds, the other agent has the possibility to retaliate the defection by defecting himself. Cooperative behaviour can be rewarded by the other agent by his own cooperative behaviour. Therefore each agent has ambivalent incentive to defect and not to defect from the cartel agreement. This is the principle of the TIT-FOR-TAT models that are applicable in market games (Tzafestas 2000).

Finitely repeated TIT-FOR-TAT games have theoretical peculiarities in connection with the so called "end game" (Schuessler 1989): In the last round, none of the agents is afraid of retaliation. Therefore, each agent assumes that the other one is going to defect and therefore defects himself. Based on this assumption, the agents do not have any more incentive to cooperative in the penultimate round and therefore defect as well. Cooperation breaks down from the end to the beginning, following the "domino effect". This is Selten's "Chain store paradox" (1978). Therefore, only

- an agent with bounded rationality,
- an agent who assumes the other agents' bounded rationality or
- an agent who does not have sufficient information about the other agent or the environment dares to act cooperatively in a finitely repeated TIT-FOR-TAT game.

Figure 13 shows a TIT-FOR-TAT model, where 2 suppliers are in a quantity competition. Cooperation occurs due to the assumption of other agents' bounded rationality or incomplete information.

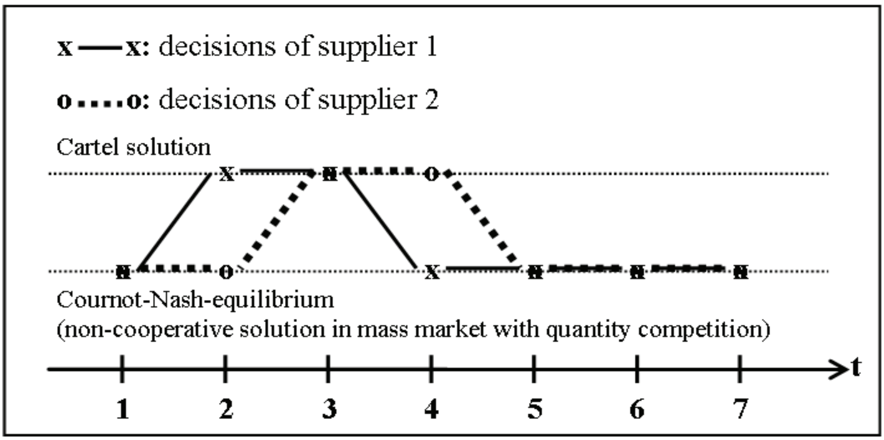


Fig. 13. TIT-FOT-TAT model: repeated market game with quantity competition and bonded rationality, the other's bounded rationality or incomplete information is assumed (by the author)

1.4.1.6. Network formation and the special case of coalition formation

Coalitions and networks can only be formed endogenously if they are mutually best strategies (Hart and Kurz 1983; Kahan and Rapoport 1984; Joshi 2006; Ray 2007; Sun et al. 2008). If one agent cannot force another one to "agree", the agreements must be self-enforcing. Self-enforceability means immunity to deviations by single agents or subcoalitions. Pareto-domination (= Pareto-efficiency) is the precondition for self–enforceability. The outcome cannot be dominated by other ones. Coalition or network formation is never unilateral. Networks are aggregations of bilateral links and therefore for each link the both participating agents have to agree. A coalition is a special case of a network where each agent is linked to each other one equally. Oppositely, in order to disband a coalition or network-link, only 1 participant needs to leave. This is shown in table 6.

Table 6. Necessary agents to form or disband a coalition or network-link

	Coalition	**Network-link**
Formation	≥ 2 agents	Exactly 2 agents
Disbandment	≥ 1 agent	1 or 2 agents

Traditionally, non-cooperative and (restricted) cooperative game theory is divided by the criterion of whether binding agreements are possible. However in dynamic setting this border often blurs. Agreements might be binding not more than over one or few rounds. There can be structural issues or contractual penalty that makes the exit from the coalition or network costly. The crucial question in coalition and network games is the stability of agreements (or the possibility of blocking agreements).

Regarding the difficulty of making binding agreements in the long run, two stability approaches of non-cooperative games become relevant in coalition and network games. Both are Pareto-efficient Nash-equilibria. They are relevant, if there is the possibility of forming a coalition or network with at least 3 agents:

- the strong Nash equilibrium,
- the coalition-proof Nash equilibrium.

Aumann (1959) defined the "strong Nash equilibria" (SNE) as follows: "An equilibrium is strong if no coalition, taking the actions of its complement as given, can cooperatively deviate in a way that benefits all of its members". In opposite to usual Nash equilibria, the strong Nash equilibrium regards the possible deviations of all conceivable coalitions instead of single agents. However that approach has two important weaknesses. Firstly, the criterion is too strict so that the SNE rarely occurs. Secondly, the subcoalitions that decide to leave the coalition do not care anymore about self-enforcement (and actually need a binding contract). Bernheim/ Peleg call this "internal inconsistency". They define "internal consistency" as the judgment of the validity of deviations by the same criteria the original agreement is judged.

Therefore Bernheim and Peleg (1987), Bernheim and Whinston (1987) proposed the coalition-proof Nash-equilibrium (CPNE). They define: "An agreement is coalition-proof if and only if it is Pareto-efficient within the class of self-enforcing agreements. In turn, an agreement is self-enforcing if and only if no proper subset (coalition) of agents, taking the actions of its complements as fixed, can agree to deviate in a way that makes all of its members better off". In other words, a coalition-proof Nash-equilibrium cannot be attacked by a Pareto-superior subcoalition that cannot be attacked by Pareto-superior subcoalitions themselves. That means internal consistency. In comparison to the strong Nash-equilibrium it is less restrictive, because internal consistency of the deviating subcoalition is a restriction on the restriction as shown in figure 14.

The CPNE has properties that make it very interesting in the context of coalition and network formation:

- CPNE coincides with Pareto–efficient solutions that are dominant equilibria (Moreno and Wooders 1996).
- CPNE almost always exist (Moldavanu 1992).

CPNE cannot be Pareto-dominated and at the same time it is not demanded that the other agents act rationally. Nouweland (2003) argues that CPNE always exists if a game has the property that additional agents always bring additional profit (superadditivity). However though this demand is relatively weak, it is not always fulfilled either.

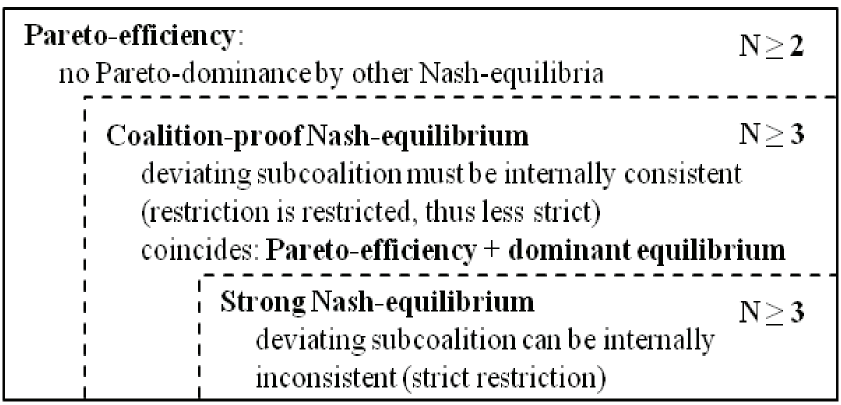


Fig. 14. Non-binding agreements: relationship of Pareto-efficient NE, strong and coalition-proof NE

In the following chapters, the stability of binding agreements is only compared with the stability notion of coalition-proof Nash–equilibria, where it is not necessary that the agreement is binding, i. e. that it is protected by a super–ordinate institution.

1.4.2. Coalition and network game theory

The fields of coalition games focused on the one hand on

- the possibility and
- the stability

of sets of allocations. On the other hand they focus on rules that determine the allocations exactly. In this paper the transferability of utility between the agents without losses is assumed (TU-games). Aumann (1961) defines the following preconditions for utility transferability:

- Utility is linear and divisible,
- There is an accepted medium (money) (Bergstrom and Varian 1985).

The generalized assumption of non-transferable utility leads to highly more complex games (NTU-games) but is not regarded in this paper.

The main feature of cooperative game theory or coalition and network game theory is that binding agreements are made (Wiese 2005). The contracts the agents make are asserted by a higher-ranking institution, usually the state.

Agents that are connected by contracts, form a “coalition”. Coalitions do not eliminate the agents as individual decision makers but act as “representative agents” for the agents. Coalitions can be instances of institutions like supply chains, cartels, syndicates, trade unions, political parties, etc. However, they are ordinarily modelled in a neutral sense, without institutional implications.

A coalition game $CG = (N, v)$ contains a non-empty set of agents and a characteristic function v that assigns outcomes to all possible coalitions (Wiese 2005). v is a correspondence (set-valued function) between finite partly ordered sets (Peleg and Sudhölter 2003):

$$v : Powerset(N) = 2^N \to \Re_+ \tag{2.11}$$

Thus characteristic functions of three agents have the following structure:

$$v(Powerset(3)) = v(\{A\}; \{B\}; \{C\}; \{A; B\}; \{A; C\}; \{B; C\}; \{A; B; C\}) \tag{2.12}$$

It is convenient and usual to normalize the outcomes of 1-agent-coalitions to 0:

$$v(Powerset(3)) = v(0;0;0; \{A; B\}; \{A; C\}; \{B; C\}; \{A; B; C\}) \tag{2.13}$$

Figure 15 gives an overview of coalition games:

- characteristic (coalition) functions,
- games with balanced cores,
- games with empty cores.

Coalition

representative player as result of binding agreement

Characteristic (coalition) function: (1.4.2.1.)

values of allsubcoalitions (components) of N players: $2^N \rightarrow \mathbf{R}$

– Possible properties: supetadditivity, convexity, balancedness
– Impulation sets: individual rationality, Pareto-efficiency
– Dynamic setting: problem of time-inconsistency of agreements

Stability notions of coalitions and profit distribution rules

Games without stable grand coalition: (1.4.2.3.)

– properties: grand coalition not stable, core does not exist (empty), stable ubcoalitions exist

Allocation set: PCore, Maschler-Aumann-Bargaining ser *M*

– properties: individual rationality, component-Pareto-efficiency, influence by subcoalitions/ outside-options

Profit distribution rule: Aumann-Drèze-rule

– properties: component-Pareto-efficiency, balanced contributions, no out side option

Games wit stable grand coalition: (1.4.2.2.)

Allocation set: core

– properties: Individual rationality, Pareto-efficiency, influence by subcoalitions/ outside-options

Profit distribution rule:

– if characteristic function convex: Shapley-rule (properties: Pareto-efficiency, balanced contributions)
– if characteristic function not convex: Aumann- Drèze-rule

Fig. 15. Coalition games (with transferable utility): characteristic coalition functions, stability notions, profit distribution rules for games with and without stable grand coalitions

As it is assumed in coalition and network games that higher-ranking institution assert the agreement (self-enforceability is not required), the stability notion is less strict than the non-cooperative games (CPNE, Aumann's strong equilibrium).

1.4.2.1. Characteristic functions

Characteristic functions capture the potential worth of each coalition or subcoalition of agents in a single numerical index. The values can be interpreted as the outcomes of optimal strategies of agents that make binding agreements. Therefore strategic games can be regarded as implicit in coalition games. The difficulties of the strategic interdependence or of the transactions themselves are separated or eliminated. In chess, for instance if the characteristic function would be known, it would simply state "white wins (value: 1)", "black wins (value: -1)" or "draw (value: 0)". Therefore the characteristic function is a collection of pre-solutions.

In a coalition game not all agents necessarily cooperate. There can be concurrently several coalitions that together form a coalition structure *CS* (synonym: partition). In that case the single coalitions are subcoalitions (synonym: components). In the special case that all agents cooperate and the coalition-structure consists of one component it is called "grand coalition". Traditionally, in the coalition games, the components of a *CS* do not overlap and are non-empty. However, this assumption is not valid in the more general network games.

If a coalition game has a coalition structure with more than one subcoalition it is a proper *CS*. As the agents decide individually rational, the notion of Pareto-efficiency is modified to the more general "component-Pareto-efficiency". In the case of only 2 connected agents (bilateral) it is the "link-Pareto-efficiency". It means that Pareto-efficiency is only achieved inside the subcoalition. In general individual rationality does not imply the wish of overall welfare.

The left Hasse-diagram (picture of a power set) in figure 16 depicts all possible subcoalitions for three agents in the form of a half-ordered closed combinatorial structure (Bilbao 2000). The right Hasse-diagram shows all possible and coalition-structures for three agents.

The rows in the both Hasse-diagrams in figure 16 are interpreted as follows:

- First row: the "grand coalition" is shown. All three agents appear at the market as one representative agent (monopoly, cartel, etc.). It is thinkable that a single agent or subcoalition blocks or raises an objection. The partition is of one component and is therefore not proper.
- Second row: on the left side all 2-person coalitions are shown. On the right side all three possible {2-1}-agent partitions are shown. As the partitions have two components they are proper. Each {2-1} partition is possibly dominated by a grand coalition, blocked by a 2-agent subcoalition or one agent out of the 2-agents'-component.
- Third row: these are "single-agent-coalitions" as the number of components equals the number of agents. Such a partition implies a strategic game without binding agreements.
- Lowest row: The empty set has the value 0. There are no exceptions.

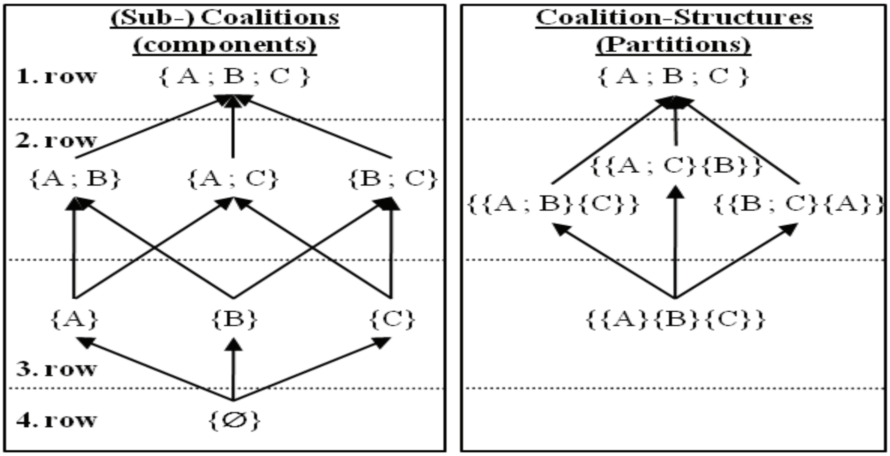


Fig. 16. Hasse-diagrams for 3 agents (left: all (sub-) coalitions; right: all coalition structures)

An imputation set (synonym: budget constraint) contains all Pareto-efficient allocations of a particular coalition. A characteristic function contains the values (total outcomes) of all possible coalitions or subcoalitions. Thus, imputation sets fulfil the minimal rules:

- individual rationality,
- Pareto-efficiency.

An imputation set is formally:

$$I.set = \left\{ x \in \Re^N : \begin{matrix} x_i \geq v_i; i = \{A; B; C\} \\ x = \sum v(\{i\}) \end{matrix} \right\} \tag{2.14}$$

Geometrically, an imputation set is an (N-1)-dimensional simplex (N: number of agents). A simplex is an n-dimensional generalization of a triangle. For instance, 4 cooperating agents in a TU-game have an imputation set in the form of a tetrahedron (3 dimensions) in a 4-dimensional space.

Figure 17 shows examples with 3 agents (all variants with 2 agents are inclusive). The three lines under the triangle represent the respective budget constraints / imputation sets for the 2-agents coalitions $\{A; B\}, \{A; C\}, \{B; C\}$. These lines (2-simplexes) are delimited by the axes due to the individual rationality (each agent obtains 0 without cooperation). In the case of 3 agents the imputation set is a triangle (3-simplex in R^3). That triangular 3-person imputation set is above the 3 2-person imputation sets. This is because in this example all agents together can achieve more profit than two agents alone (superadditivity). At the edges, one of the three agents does not obtain anything from the profit. Furthermore, in the corners one agent obtains everything and the other two nothing. Usually this 3-persons imputation set is depicted as projection triangle, where the origin of the coordinate system is exactly in the middle of the image, as shown in the next chapters.

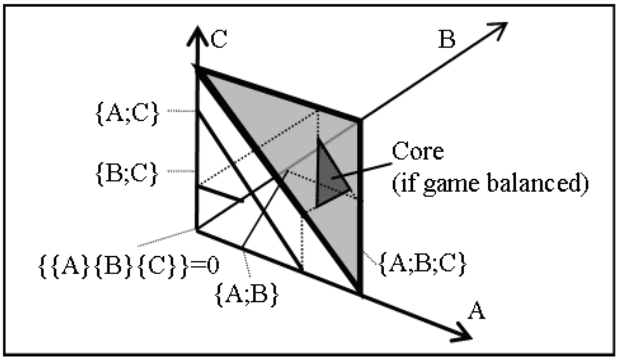


Fig. 17. Imputation sets of a superadditive and balanced characteristic function with 3 agents for all 2-agents' subcoalitions and the core (by the author)

Three important properties of characteristic functions in the context of dominance or blockings are:

- superadditivity,
- balancedness,
- convexity.

Superadditivity means that the total profit increases monotonously if new agents enter the coalition. The imputation sets in figure 17 result from a super-additive characteristic coalition function with 3 agents (because the triangle is above all 2-agents imputation sets). Formally expressed that means for all sub-coalitions $R, S \subseteq N$, if the coalitions do not overlap:

$$v(R) + v(S) \leq v(R \cup S) \tag{2.15}$$

Balancedness is crucial for the dominance of the "grand coalition" over the subcoalitions. The following relation ensures balancedness:

$$v(N) \geq \left(\frac{1}{N-1}\right) \times \sum_{j=1}^{N} v(N \setminus j) \tag{2.16}$$

With a balanced characteristic function the "grand coalition" provides a higher value than the "sum of all coalitions where 1 agent is missing, divided by the number of these". Then it is possible in at least one point to form a grand coalition in a way that it cannot be blocked by any subcoalition (or single agent).

In characteristic functions with 2 agents balancedness is identical with superadditivity. In the case of 3 agents, superadditivity is implied. Balancedness has the following condition:

$$v(A;B;C) \geq \frac{v(A;B)+v(A;C)+v(B;C)}{2} \tag{2.17}$$

In the case of 3 agents the denominator has to be 2, in order to provide the threshold for the stability of the grand coalition. If the threshold is not reached, one of the 3 subcoalitions $v(A;B)$, $v(A;C)$ or $v(B;C)$ are able, i. e. as intended rational agents are going to block the grand coalition and divide the profit among themselves.

Convexity of a characteristic function means that the larger a coalition the higher is the marginal contribution of any entering agent. Convexity implies superadditivity but goes one step further (Topkis 1998). If a new agent enters the coalition, all agents in the coalition benefit. A coalition game (N,v) is convex if for all (sub-) coalitions S, S' with $S \subseteq S'$ the following is fulfilled:

$$v(S \cup i) - v(S) \leq v(S' \cup i) - v(S') \tag{2.18}$$

In order to illustrate superadditivity, balancedness and convexity, four examples of characteristic functions are given:

$$v = (0;0;0;40;60;50;0) \tag{2.19}$$

$$v = (0;0;0;40;60;50;65)$$

$$v = (0;0;0;40;60;50;75)$$

$$v = (0;0;0;40;60;50;120)$$

The characteristic function 1 is not superadditive because the “grand coalition” provides a profit of 0. Therefore balancedness and convexity are disproved as well. Example 2 is superadditive, what means that the grand coalition provides the highest value. However as it is not balanced, the grand coalition is dominated by subcoalitions. Example 3 is superadditive and just balanced. Therefore there is exactly one profit distribution where the grand coalition cannot be dominated. Example 4 additionally fulfils convexity. Everyone has become better off by the entering of the last missing agent.

In convex characteristic functions network effects (or network externalities) occur. For instance, the more people use a technology, institution or standard (phones, industrial norms, virtual markets, etc.) the more utility arises for each single user.

Repeated coalition games are a sequence of static games whose value is determined by the (discounted) stream of payoffs. The characteristic function is time-separable, i. e. the agents are aware and are able to recognize their valuation of the game at any point of time. These are the sequences:

- sequence of characteristic functions:

$$\left(v^1, \ldots, v^T\right)$$

- sequence of coalition games:

$$\left(CG^1\left(N, v^1\right), \ldots, CG^T\left(N, v^T\right)\right)$$

For instance, agents conclude a binding agreement in order to accumulate capital over several periods. Furthermore discounting can be considered after the principle of net present value (NPV).

If coalition games are repeated, the problem of time-inconsistency becomes important. Changing environment, bounded ability of contemplation and incomplete information cause permanent changes in preferences. The stability notion of CPNE is relevant, if the agreement is not perfectly binding. This paper restricts on time-inconsistency in games with non-balanced characteristic function so that there exists an excluded agent that represents the outside option.

1.4.2.2. Games with stable grand coalition: dominance, profit distribution

The core is the set of possible outcomes for a grand coalition that cannot be blocked by any other coalition or agent (Bhattacharya 2004; Kranich et al. 2005). It is the most important stability or dominance notion for grand coalitions (Jain and Vohra 2006). It is always a subset of an imputation set (as shown in figure 17) and therefore at least fulfils its rules "individual rationality" and "Pareto-efficiency". Additionally, as the Russian mathematician Bondavera (1963) and Shapley (1967) have shown, the core exists if and only if the characteristic function is balanced (formula 217, Bondavera-Shapley-theorem). The core is defined as follows:

$$Core = \left\{ x \in \Re^N : \begin{array}{c} \sum_{i \in S} x_i \geq v(S) \forall S \in 2^N \setminus \{empty\_set\} \\ i = \{A; B; C\} \\ x = \sum v(\{i\}) \end{array} \right. \quad (2.20)$$

The first line of the equation (2.20) shows that the summarized profit of all agents has to be higher than of any subcoalition, and cannot be blocked by any of them. Therefore the core only refers to the grand coalition. The last line defines the efficiency of the distribution.

Profit distribution rules provide or propose a certain distribution that fulfils certain criteria (axioms) like Pareto-efficiency or fairness (Holler and Owen 2001). They can be used to predict negotiation results. Common synonyms for "profit distribution rules" are:

- allocation rules (values),
- profit division rules (values),
- decision rules (values),
- power indices.

Usually these values depend on the relative power of the agents. Therefore the total outcome of the game is compared with the total outcome it would have without the agent what is called the "added value" or the "contribution":

$$\text{Added value/contribution of player } i = \text{Value(coalition with } i) - \text{Value(coalition without } i). \quad (2.21)$$

Power is also caused by threats. Then the "contribution" consists of not implementing the threat in comparison with implementing.

The most popular profit distribution rule in literature (Shapley 1953) that depicts relative power is the Shapley-rule Sh (for grand coalitions). In order to keep the nomenclature consistent, it is called in the thesis "Shapley-rule". It assumes that the agents do not know ex ante in which order the grand coalition will be formed and that they are risk neutral. It is defined as follows:

$$Sh_i(v) = \sum_{S \subseteq N \setminus \{i\}} \frac{|S|!(n-|S|-1)!}{n!} [v(S \cup \{i\}) - v(S)] \quad (2.22)$$

The squared brackets on the right side represent the added value in the sense of equation (2.21). In the Shapley-rule all possible orders of "entering the coalition till the grand coalition is established" are decomposed by combinatory. The added values of each agent by entering a coalition are summarized and are put into relation with each other.

There are several equivalent axiom systems for the Shapley rule. Two important systems are presented here. The first one is the original proposition by Lloyd Shapley, the second one by Roger Myerson. Shapley (Winter 2001) defines the axioms "Pareto-efficiency", "symmetry", "linearity" and "dummy agent". Pareto-efficiency determines that the complete outcome is distributed among the agents. Symmetry is the fairness condition that was firstly written down by Aristotle (Stanford Encyclopedia of Philosophy 2007). The relative outcome of each agent only depends on the relative contribution. Linearity assures the invariance to linear transformations and the dummy agent axiom determines that those agents who do not contribute anything to the common profit do not obtain anything of it. Only the Shapley-rule exactly fulfils there requirements.

However there are other equivalent axiom systems that yield the Shapley-rule. Roger Myerson has proposed a rule for games with communication restrictions and has shown that the Shapley-rule is a special case. His axiomatization of the Shapley-rule has two requirements (Myerson 1980):

- Refinement of Pareto-efficiency: valid for N and all subsets of N
- Balanced contributions.

Thus in the case of 3 agents, not only the total outcome is distributed, but also the distribution among all pairs of agents is component-Pareto-efficient. The refined Pareto-efficiency axiom is:

$$\text{For all } S \subseteq N : \sum_{i \in N} Sh_i(v) = v(S) \tag{2.23}$$

The axiom of balanced contributions means for the grand coalition or a subcoalition that the cutback of outcome for each agent is equal, independent from which agent exits. Myerson describes it as the "equality of withdrawal threats". For all $S \subseteq N$:

$$Sh_i(v(S)) - Sh_i(v(S \setminus \{j\})) = Sh_j(v(S)) - Sh_j(v(S \setminus \{i\})) \tag{2.24}$$

For the stability (= non-blockability) of allocations that are determined by the Shapley-rule it is important to distinguish whether the characteristic function is convex or not (Shapley 1971). If the characteristic function is:

- convex: the Shapley-rule lies inside the core,
- non-convex: it lies outside the core.

Therefore only with convex characteristic functions the Shapley-rule proposes an allocation that cannot be blocked by subcoalitions.

Despite of the wide applicability the Shapley-rule has its limitations. These are:

- It can be regarded as a recommendation for fair division. However it neglects the crucial questions of stability and dominance (that are covered by concepts like the core).
- Profit is only distributed among grand coalitions, when no subcoalition is able to block.
- It is calculated before the grand coalition started to form (ex ante rule).
- It is assumed that the agents care about the order of coalition entrance they do not know it and are risk neutral.

– In the original version the utility is transferable and the distributed good is homogeneous.

Now three examples are given to illustrate the relationship between the core and the Shapley-rule in the case of balanced characteristic functions. These can be snapshots of a dynamic game where formerly made agreements become time-inconsistent:

$$\left(G^1\left(N,v^1\right),G^2\left(N,v^2\right),G^3\left(N,v^3\right)\right)$$

(right)

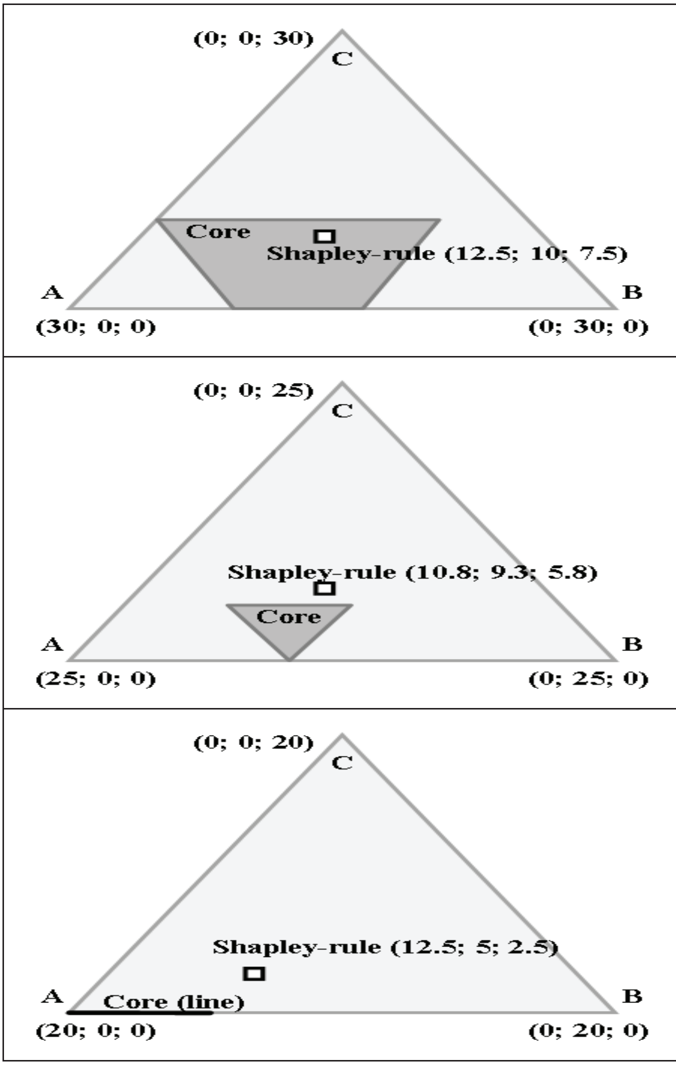
In the left image of figure 18 the characteristic function

$$v^1=\left(0;0;0;20;15;10;30\right) \tag{2.25}$$

is given. The last value 30 is the common profit that can be allocated with the restrictions of the imputation set. It determines the size of the triangle. A subcoalition $\{A;B\}$ achieves 20, $\{A;C\}$ achieves 15 and $\{B;C\}$ 10. In all points of the imputation set each agent contributes to the common profit. However at the edges the agent of the respective opposite corner is excluded from profit distribution. Therefore the edges represent the 3 possible (2-agents) subcoalitions. At the corners, one respective agent gains everything, and is therefore a dictator. The core contains all profit distributions that cannot be blocked by subcoalitions. However the lighter areas are not stable because they can be blocked. The Shapley value proposes a “fair” division of the total profit into (12.5; 7; 10.5) before the agents have started to enter the game. As the Shapley-rule lies in the core, the game is convex and a stable and fair profit distribution is possible. The middle image of figure 18 the characteristic function

$$v^2=\left(0;0;0;20;15;10;25\right) \tag{2.26}$$

is depicted. The grand coalition profit is decreased to 25. Therefore the imputation set triangle is smaller than in the left image. The core is relatively small because the agents A and B can almost achieve the grand coalition profit without C. The function is not convex so that the Shapley-rule lies outside the core. It can still be profitable all if C enters the $\{A;B\}$-subcoalition, but C cannot expect a “fair” solution (that is based on “balanced contributions”, Shapley-rule, etc.). The right image of figure 18 shows the characteristic function.



Coalition Values	
AB	20
AC	15
BC	10
ABC	**30**
Shapley-rule	
A	12.5
B	10
C	7.5

Coalition Values	
AB	20
AC	15
BC	10
ABC	**25**
Shapley-rule	
A	10.8
B	9.3
C	5.8

Coalition Values	
AB	20
AC	15
BC	0
ABC	**20**
Shapley-rule	
A	12.5
B	5
C	2.5

Fig. 18. Convex characteristic function with Shapley-rule inside the core (left), balanced non-convex characteristic function with Shapley-rule outside the core (middle), balanced non-convex characteristic function with edge-core, participation of agent C irrelevant

$$v^3 = (0;0;0;20;15;10;20) \tag{2.27}$$

As the whole core is at the edge, all profit distributions inside the core are also stable for the subcoalition $\{A;B\}$. However, only coalitions where agent A participates make profit. If there is already the subcoalition $\{A; B\}$, C can join but neither brings harm nor utility, so that each attempt of C of participating in the profit division can be blocked. On the other hand if B claims a share that is >5, C can block it as well, so that despite of being "excluded", C has tremendous power on the profit distribution (outside option). Thus it is a peculiar case that the core or elements of the core lay at the edge, where it does not matter whether the grand coalition "officially" exists as it is equivalent to an according 2-agents-coalition (2 agents can make a stable agreement without officially leaving the grand coalition).

The change of the characteristic functions over the time leads to time-inconsistency of agreements. Both:

- stability, fairness and
- the bindingness of the agreement,

are challenged. Hence, if the costs of breaking the agreement are "sufficiently low" the stricter notion of stability of non-cooperative games (i. e. CPNE) has to be investigated.

1.4.2.3. Games without stable grand coalition (empty core): dominance and profit distribution in games with coalition structures

If the core is empty, each grand coalition can be blocked by subcoalitions. Coalitional games with proper coalition structure come into the focus. Casajus and Tutic (2007) propose the "partition core" (PCore), a generalization of the core for coalition structures. An important profit distribution rule for games with coalition structures is the Aumann-Drèze-rule (Aumann and Drèze 1975).

An approach that is very close to the PCore and is well investigated is the bargaining set M that was introduced by Maschler and Aumann (Davis and Maschler 1962; Aumann and Maschler 1964). It is a generalization of the core but provides information about the stability of the profit distribution if the core is empty. In the context of the bargaining set, a negotiation is described as a sequence of objections and counter-objections. It is regarded as a kind of stability when no objection (that is not neutralized by counter-objections) is made against a certain profit distribution. The objection can also be made by any subcoalition of agents so that concept of strong Nash equilibria is implicit in the bargaining set M (thus CPNE implicit as well). In the case of convex characteristic functions the core and the bargaining sets are identical (Peleg and Sudhölter 2003). The bargaining set M is the set of stable coalitionally rational payoff configurations with the

- payoff configuration: (S, x) and
- coalitional rationality:

$$\sum_{i \in S} x_i \geq v(S) \text{ for all } S \subseteq N \tag{2.28}$$

However, the disadvantage of all PCore approaches is that the does not exist any general solution algorithm yet, so that only particular problems can be analyzed in a structured way. Hence, in general it is not possible to state the complexity class of calculating a PCore. Only if it is specified in a way that the calculability is assured, complexity does not exceed NP-completeness.

The Aumann-Drèze-rule implements a Shapley-rule like calculation within a "productive" (2-agents') subcoalition. In a coalition structure with 3 agents where A and B are productive $CS = \{\{A;B\}\{C\}\}$, the profit is distributed component-Pareto-efficiently and in a balanced way (in this case equally) between A and B. That means that for $\{A;B\}$ as the productive component:

$$\sum_{i \in \{A;B\}} AD_i(v(\{A;B\})) = v(\{A;B\}) \tag{2.29}$$

is valid. Thus, the subcoalition profit is distributed as follows:

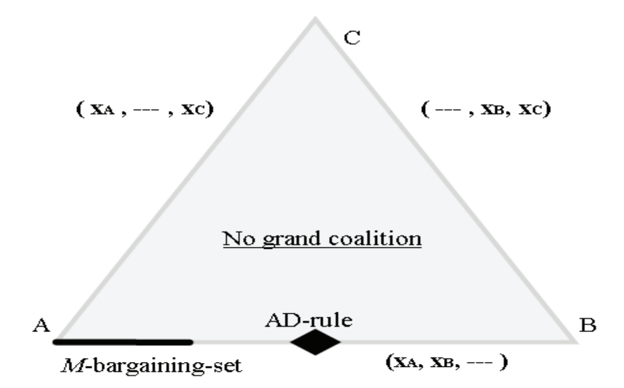
$$Aumann - Drèze - rule = \left(\frac{v(\{A;B\})}{2}, \frac{v(\{A;B\})}{2}, 0 \right) = \left(\frac{1}{2}, \frac{1}{2}, 0 \right) \text{(normalized)} \tag{2.30}$$

The Aumann-Drèze-rule is a generalization of the Shapley-rule because in the case that the productive subcoalition is the grand coalition, both profit distribution rules are identical.

In the following example with 3 characteristic functions (i.e. dynamic setting), which is shown in figure 19, the grand coalition is forbidden. The bargaining set M is similar in this case with the edge-core of the right image of figure 18. The left image of figure 19 shows the characteristic function:

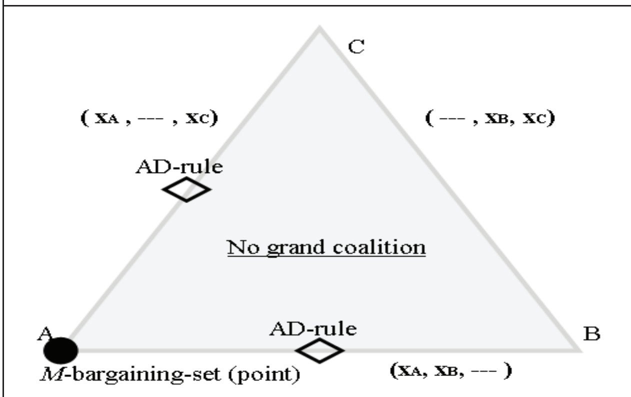
$$v_1 = (0;0;0;20;15;0;0) \tag{2.31}$$

If the partition $\{\{A;C\}\{B\}\}$ is formed, firstly all payoffs that fulfil $(\{A;C\};(x_A, \circ, 15 - x_A))$ with $x_A \in [0;15]$, are candidates for an agreement between A and C. However the agents A and B can bring the objection (that cannot be countered):



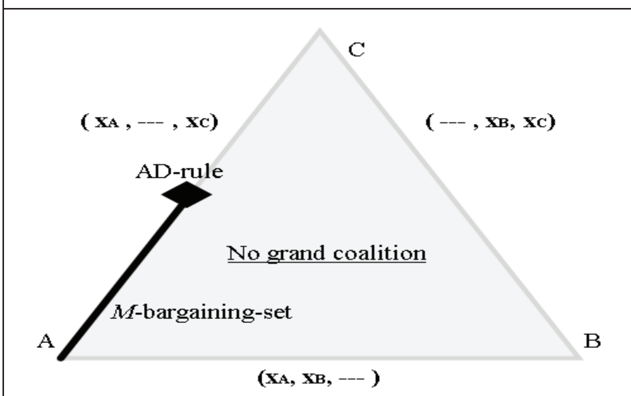
Coalition values	
AB	20
AC	15
BC	0
ABC	0

Aumann-Drčze-rule	
A	10
B	10
C	0



Coalition values	
AB	20
AC	20
BC	0
ABC	0

2 Aumann-Drčze-rule			
A	10	*A*	10
B	10	*B*	0
C	0	*C*	10



Coalition values	
AB	20
AC	40
BC	0
ABC	0

Aumann-Drčze-rule	
A	0
B	20
C	20

Fig. 19. Cases of bargaining set M (no stable grand coalition), Aumann-Drèze-rule not stable against blocking by $\{B;C\}$-coalition (left, eq. 2.31), B and C of equal power, 2 Aumann-Drèze-rules that are both not stable (middle, eq. 2.32), Bargaining set M with stable Aumann-Drèze-rule (right, eq. 2.33)

$$(\{A;B\};(x_A,20-x_A,\circ)) \text{ with } x_A \in [0;20]$$

Therefore no coalition between A and C is stable in the sense of the bargaining set. If the partition $\{\{A;B\}\{C\}\}$ is formed, the candidates for an agreement between A and B are:

$$(\{A;B\};(x_A,20-x_A,\circ)) \text{ with } x_A \in [0;20].$$

The agents A and C can only bring the objection (that cannot be countered):

$$(\{A;C\};(x_A,\circ,15-x_A)) \text{ with } x_A \in [0;15].$$

Thus the remaining M-bargaining set is:

$$(\{A;B\};(x_A,20-x_A,\circ)) \text{ with } x_A \in [15;20].$$

The middle image of figure 19 shows the characteristic function

$v_2 = (0;0;0;20;20;0;0)$, and the right image shows (2.32)

$$v_3 = (0;0;0;20;40;0;0) \quad (2.33)$$

In the case of v_2, B and C give A the same proposal. B and C bid against each other till A gains the complete profit. In v_2 C has the better proposal, but the possible outcomes are influenced by B.

The bargaining set with prohibited grand coalition considers the outside option because it is influenced by the excluded agent. Profit distributions inside the bargaining set are also stable in the sense of CPNE. Due to the fact that the Aumann-Drèze-rule generally is not part of the bargaining set M, solutions that are based on the Aumann-Drèze-rule are in general not stable.

1.4.2.4. Network games: dominance and profit distribution in games with link restrictions

In coalition games it is the classical hypothesis that all coalitions of agents are possible without restrictions and the intensities of the connections are identical. However, that is a simplification that often is not justifiable. The formation of coalitions might be restricted due to structural issues, laws, culture, ideology, etc. For instance one agent can be a business partner of two agents. However these two other agents are not connected among each other. This generalization leads to the field of “restricted cooperative game theory” or “network games”, introduced by Myerson (1976), Aumann and Myerson (1988).

Network games $NG = (N, v, g)$ are based on non-directed graphs where bilateral links between the agents are united to networks. In the dynamic setting it is:

$$NG^1 = (N, v^1, g), \ldots, NG^T = (N, \mathrm{v}^T, g) \tag{2.34}$$

As shown in Table 7 the number of possible subnetworks g (excluding the empty network) for N agents is 2^{N-1}. Therefore it is identical with the number of possible subcoalitions.

Table 7. All possible networks with 3 agents based on bilateral links

Agents	(Sub-) networks g		
3	$\{\{AB\}\{AC\}\{BC\}\}$ (coalition game)		
	$\{\{AB\}\{AC\}\}$	$\{\{AB\}\{BC\}\}$	$\{\{AC\}\{BC\}\}$
2	$\{AB\}$	$\{AC\}$	$\{BC\}$

Coalition games are the special case where all agents are connected with each other, i. e. coalitions are networks with $\frac{m(n-1)}{2}$ links for N agents (in Table 2: 3 bilateral links with 3 agents). Restrictions are the crucial feature of network games. In order to describe a network, it is necessary to define

- the characteristic (network) function and
- the restrictions

The information about the restriction is usually given by the maximally formable network (here: max-network). For instance, if the connection between B and C is forbidden, the "max-network" is:

$$g = \{AB, AC\} \tag{2.35}$$

The matriod in figure 20 depicts that such a restriction has tremendous impact on the possibilities of network formation. The rows of the matroid represent the numbers of bilateral links. In the

- 1. row: there are 3 links, all agents are connected with each other, grand coalition (S = N), corresponds to a typical coalition game.
- 2. row: only the 2-link network $\{\{AB\}\{AC\}\}$ is possible, if all agents are involved
- 3. row: $\{AB\}$ and $\{AC\}$ are possible, corresponds to subcoalitions.
- 4. row: empty network, the game is purely non-cooperative.

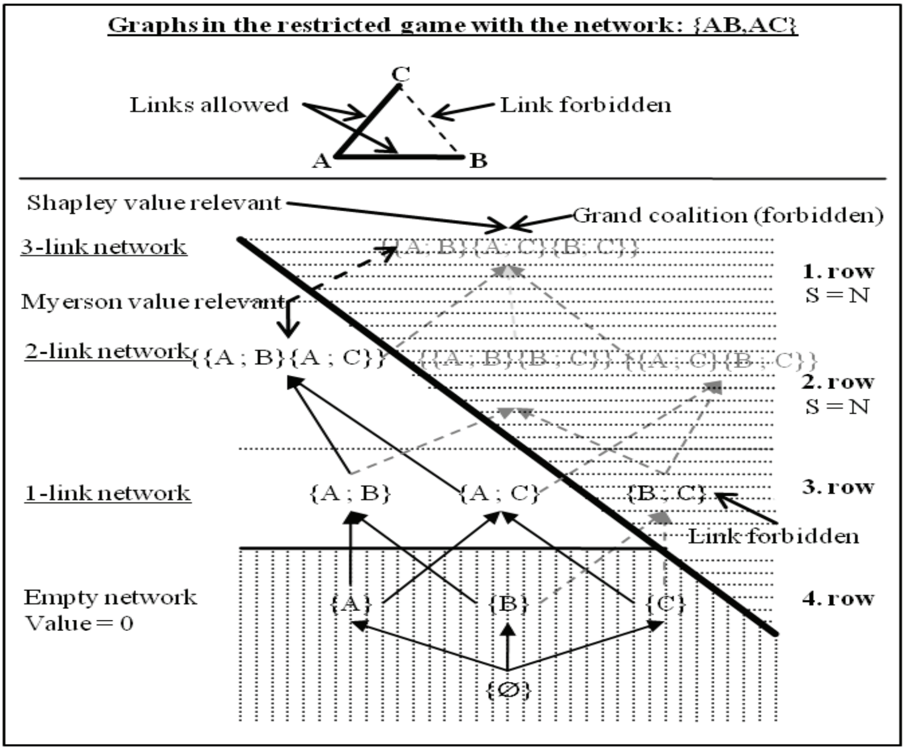


Fig. 20. Impact of restriction on possible networks with $g = \{AB, AC\}$ (by the author)

Thus, network games have the possibility of depicting the interaction between 3 agents much more precisely than the (traditional) coalition games. However this precision is bought by tremendously higher computational complexity. Many concepts of network games are deep in the complexity class "NP-hard" (Pin 2005).

Basically, all concepts of coalition games can be generalized to network games. However, that field is in its pioneer phase, literature is still sparse and fragmentary. Recent development has been triggered by Jackson (2003 a, b), Bilbao (2000), Jackson and Nouweland (2003), Demange and Wooders (2005). Just in 2008, a generalization of the concept of the core (Zhao 2008) has been proposed. Such contemporary contributions can be regarded as introductory and exemplify the immaturity of network games.

Figure 21 shows the approaches of network games classified by the property of balancedness of the characteristic network function. Therefore it is furthermore assumed that utility is transferable.

Network: aggregation of bilateral coalitions

Characteristic network functions (Myerson functions):
values of all allowed subnetworks
– Dynamic setting: problem of instability of agreements due to time-inconsistency

Stability notions of networks and profit distribution rules

Games without stable restricted grand coalition: (1.4.2.5)
– properties: network-core does not exist (empty), stable subnetworks exist, outside option

Profit distribution rule: Myerson-rule for coalition structures
– properties: link-Pareto-efficiency, balanced links, no outside option

Games with stable restricted grand coalition:

Allocation set: network-core
– properties: individual rationality, link-Pareto-efficiency, influence by subnetworks, but no blocking

Allocation rule: Myerson-rule
– properties: link-Pareto-efficiency, balanced links

Fig. 21. Network games as generalization of coalition games (with transferable utility), characteristic network functions, stability notions, profit distribution rules for games with and without stable restricted grand coalitions

Characteristic network functions (Myerson functions)

The characteristic network functions (Myerson functions) define the values of all possible networks and are determined by the single bilateral links with g_s and an arbitrary network with $S \subseteq N$ agents:

$$v^{g_s} = \sum_{link \in g_s} v(link) \qquad (2.36)$$

In a characteristic network function, each possible (sub-) network obtains a value. Due to the enormous amount of possibilities and the tremendous complexity, this paper restricts on the example of characteristic network functions with 3 agents and 1 forbidden link (here between the agents B and C). This is an example of a balanced characteristic network function:

$$v_{ch.6.1}^{g} = \begin{cases} 0; |S| \leq 1 \\ 60; g = \{AB\} \\ 40; g = \{AC\} \\ 80; g = \{AB, AC\} \end{cases} \tag{2.37}$$

Restricted grand coalitions: balancedness and Myerson-rule as profit distribution rule

As in the coalition games, balancedness is the precondition for the existence the biggest possible network with restrictions, the restricted grand coalition. The referring stability approach is the "network-core" (Zhao 2008) that is a core with restrictions, (very similar alternative: "pairwise stable network", Jackson and Nouweland 2003). A profit distribution in the network-core is stable because it cannot be blocked by subnetworks (or single bilateral links). The network-core is a generalization of the core in ordinary coalition games and has the properties (not an axiom system):

- Individual rationality,
- Component-Pareto-efficiency,
- Influence by all players.

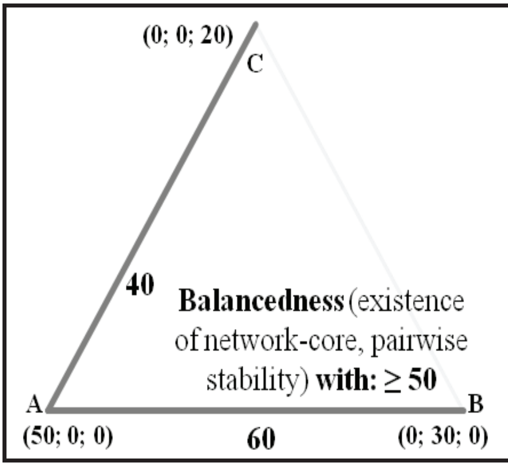
Whether the characteristic network function is balanced, depends on the value of $g_{\max} = \{AB, AC\}$. The question is: What is the minimal value of $g_{\max}$, so that there exists a profit distribution that is not blockable by 2 agents through a single link? In the case of 3 agents and 2 links, Bondavera/Shapley's formula (referring to formula 2.17) is valid:

$$v(N) \geq \left(\frac{v^{\{AB\}} + v^{\{AC\}}}{2} \right) \tag{2.38}$$

Figure 22 shows, how in the case of $v^{\{A;B\}} = 60$ and $v^{\{A;C\}} = 40$, the balancedness is asserted with $v^{\{\{A;B\}\{A;C\}\}} \geq 50$.

The profit distribution rule for restricted grand coalitions is the Myerson-rule (Navarro and Perea 2005; Pin, 2005; Kajii et al. 2008) that is a generalization of the Shapley-rule (referring to formula 2.22). Instead of subcoalitions that form the grand coalition stepwise, subnetworks form the restricted grand coalition stepwise. In figure 22, there are 2 paths that lead to the restricted grand coalition:

$$g^{\{AB\}} \rightarrow g^{\{\{AB\}\{AC\}\}}; g^{\{AC\}} \rightarrow g^{\{\{AB\}\{AC\}\}} \tag{2.39}$$



Restricted grand coalition: $\{AB; AC\}$			
Subnetwork values			
AB	60	AC	40
Just balanced			50
Myerson-rule for $\{\{AB\}\{AC\}\} = 80$			
A	B		C
50%	31,25%		18,75%

Fig. 22. Bilateral links and pairwise stability of the network with number example

The Myerson-rule is the expected value of the contribution, which the single agent gives, if it is not known yet, in which order the restricted grand coalition is going to be formed:

$$My_i(v) = \sum_{S \subseteq N \setminus \{i\}} \frac{|S|!(n - |S| - 1)!}{n!} \left[v(g_{S \cup \{i\}}) - v(g_S) \right] \quad (2.40)$$

Myerson's original axiom system is:

− Component-Pareto-efficiency for each link:

$$\sum_{i \in C} My_i(N, v, g) = v(C) \text{ for each link} \quad (2.41)$$

− Axiom of pairwise balanced contributions:

$$\begin{aligned} &My_i(N, v, g) - My_i(N, v, g \setminus \{j\}) = \\ &My_j(N, v, g) - My_j(N, v, g \setminus \{i\}) \end{aligned} \quad (2.42)$$

These two axioms can only be fulfilled by the given formula for the Myerson-rule. For the characteristic network function $v_{ch.6.1}$ the Myerson-rule for the 3 agents is:

$$My_{AB;AC} = (50\%, 31.25\%, 18.25\%) \quad (2.43)$$

1.4.2.5. Network games without stable restricted grand coalitions

Non-balanced characteristic networks functions lead to a generalization of the idea of coalition structures to restricted cooperative games. The restricted grand coalition can be blocked by subnetworks that are restricted subcoalitions. However due to the fact that

- individual rationality and
- component-Pareto-efficiency

are the preconditions for stability on the subnetworks, a generalization of the PCore (i. e. bargaining sets) to network games is possible. However this problem is not solved yet. The approach of pairwise stability (Jackson and Nouweland 2003) leads into this direction.

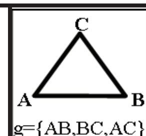
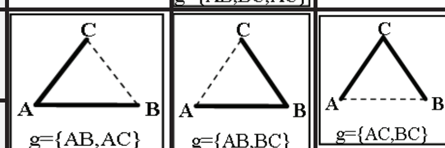
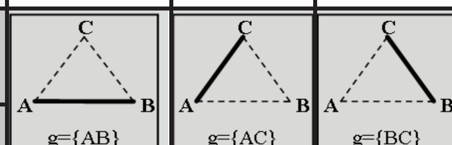
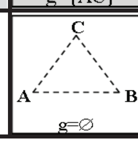
Relevant profit distribution rules / number of links	**All possible networks with 3 agents**
Shapley Links: 3 of 3	
Myerson Links: 2 of 3	
Aumann-Drèze = Myerson for coalition structures **(ADMCS, outside-option not considered)** Links: 1 of 3	
No rule (no agreements) Links: 0	

Fig. 23. Relevant profit distribution rules and number of links of all possible networks with 3 agents (by the author)

The profit distribution rule is the Myerson-rule for coalition structures, which is just deployed on the productive component. In order to distinguish it from the Myerson-rule for restricted grand coalitions, it is called in the thesis Myerson-rule for coalition structures (It must not be confused with the CS-rule for a-priori unions by Owen (Holler and Owen 2001) that is not relevant in the paper). If the subcoalition is unrestricted, the Myerson-rule for coalition structures coincides with the Aumann-Drèze-rule. In order to symbolize that both rules are identical for the investigated case of 3 agents' coalition structures, it is abbreviated as: $ADMCS - rule$. For instance, taking the characteristic network function of chapter 1.4.2.4, the ADMCS-rule is:

$$ADMCS - rule = (30{,}30{,}0) \tag{2.44}$$

Figure 23 depicts the relevant profit distribution rules for the particular 3 agents' networks. The preceding chapters have shown that the Shapley-rule refers to the network without restrictions and the Myerson-rule refers to a network, where all agents participate, but there is a restriction. In the case of coalition structures, it is the ADMCS-rule, which ignores the possible impact of the excluded agent on the profit distribution (no outside option).

1.4.3. Profit distribution rules in games with private information

If one agent is able to hide information from another one, it is the case of information asymmetry between the agents, and the principal-agent theory provides some profound insights (Göbel, 2002). It has to be distinguished between

- private information of each agent and
- public information (common knowledge).

The profit distribution rules of the "cooperative game theory" unite the notions of Pareto-efficiency and symmetry of profit distribution. Even with private information, where the agents' expected utility is maximized, there is no need to construct profit distribution rules in a randomized way. It is not necessary to use the complex "mixed strategies" for the coalition or network formation. Instead for simplification, the expected values can be regarded as "deterministic". These pseudo-deterministic values can be included into the set of feasible profit distributions.

Holström and Myerson (1982) modify the definition of Pareto-efficiency for the case of incomplete information: „a decision rule is efficient iff (if and only if) no other feasible decision rule can be found that may make some individuals better off without ever making any other individuals worse off".

In the question of feasibility of decision rules, it is distinguished between whether incentive-compatibility for the revelation of private information is required or not required. Thus, in models with private information it has to be defined, if or under which condition the agents reveal their private information.

“Better off” and “worse off” refer in the context to the paper to the expected utility based on the respective private information (not public information). Consequentially, there is no “outside planner” that can determine the interests of the agents. The “Pareto-efficient outcome” cannot be based on the real preferences of all agents but only on the revelations or assumption of the real preferences by all agents, and the mutual assumption of the other assumptions and so on.

Hence, the profit distribution rules are not modified if private information exists.

1.4.4. The time-inconsistency of agreements in games with coalition structures and outside-option

In dynamic setting circumstances steadily change, as the agents change their preferences and the exogenous factors (environment). Additionally, as rationality is restricted by contemplation and information problems, agents who intend to act rationally are in a permanent process of learning and forgetting. Learning can be understood as

- the improvement of skills or
- the reduction of incomplete information.

Obliviousness (or imperfect recall) can be regarded as an antagonistic force to learning or simply learning with negative sign. It is the inability to remember all obtained knowledge (Kuhn 1953).

Table 8. Relationship of sets of stable profit distributions, profit distribution rules, outside option (by the author)

	Sets of stable profit distributions	Profit distribution rules
Grand coalition	Core	Shapley-rule
	Influence of all agents	
Coalition structure	Partition core	ADMCS-rule
	Influence of outside option	No influence of outside option
Restricted grand coalition	Restricted core (“Network-Core”)	Myerson-rule
	Influence of all agents	
Restricted coalition structure	Restricted partition core	Myerson-rule for coalition structures
	Infuence of outside option	No influence of outside-option

Time-inconsistency of agreements is ubiquitous (Yeung, Petrosyan 2006). Therefore in dynamic setting the stability notion of solutions has to be refined.

E. g. the net present value for breaking the contract can be compared with not breaking (Hellman 2008). The outside option is the offer by an excluded agent to a participating agent to break an existing agreement in order to start a new one. As soon as it is advantageous, rational agents (single agents or groups) break the agreement (Casajus 2007). After Harsanyi (1977) the outside option can refer to agents:

- that are within the agreement group or
- that are partly within the group and partly excluded.

In the thesis only the case of 3 agents is regarded, where one agent is outside the cooperation and tries to "seduce" one of the 2 cooperating agents.

Table 8 depicts all sets of stable profit distributions (based on the core) and the corresponding profit distribution rules regarding the question of the outside option. The outside option by excluded agents is only relevant for non-balanced games.

1.5. The frame of further research

Based on the state of the art investigation of co-opetition, the foundations of the co-opetition theory should be developed. This foundation should comprise:

- the definition of co-opetition and a co-opetition model,
- the development and explication of a set determinants of a co-opetition model,
- the deployment of game theory as the mathematical instrument.

Typical problems that may be treated in co-opetition models are

- the prediction of negotiation results on the basis on negotiation power,
- the analysis of the stability of certain agreements,
- the analysis of the stability of certain industrial supply chain structures.

The agents and their relationships should be depicted in an industrial supply chain where

- the relationships of an enterprise with its competitors, complementors, suppliers and customers are illustrated,
- it is distinguished between individual customers and mass markets,
- it is distinguished between potential and actually participating agents.

A new profit distribution rule should be developed for 3 agents, which considers the impact of the excluded agent, i.e. the outside-option in coalition structures. It should be shown in how far or in which cases this profit distribution rule is more appropriate than the Aumann-Drèze-rule that is equal with the Myerson-rule on coalition structures in industrial supply chains with 3 agents.

It should be shown for

- mass markets and
- for individual customers

in how far stable agreements or at least tacit cooperation can be achieved.

Games with mass markets are barely predictable, having contradictory arguments in favor of more competitive and more cooperative relationships among the suppliers. An overview should be developed that explicated these contrary incentives.

In the case of individual customers it should be discussed which profit distribution rule provides the best prediction of negotiation outcomes. Therefore it should be distinguished between

- static models, i. e. where the negotiation takes place uniquely and is irrevocable,
- dynamic models, where it is possible to change the cooperation partner ex post and the outside option is relevant,
- dynamic models, where it is not possible to change the cooperation partner ex post and the outside option is not relevant.

The impact of information processing, i.e. learning on agreement stability should be explicated.

The mass market models and the individual customer models should be simulated with ideal-typical numbers. Experimental verifications should be implemented in order to prove or disprove the theoretical predictions.

Table 9 shows the subchapters of the chapters 2 and 3 with the treated issues:

Table 9. Subchapters of the chapters 3 and 4 with the treated issues

Chapter	Issue	Sub-issue
3.1	Definition of co-opetition	
3.2	Industrial supply chains	
3.3	Time-inconsistency of agreements	Ubiquity
3.4		Profit distribution rule with outside option
3.5	Stability of agreements	Mass markets
3.6		Individual customers
4.2	Practical investigation with participants via the internet	Mass markets
4.3		Individual customers
4.4		Comparison of experimental results and theoretical predictions

1.6. Chapter summary

- The material is mainly collected from literature. The main contributions by the author are the figures and tables.
- A human decider cannot act as a homo economicus due to limited capabilities of contemplation and limited information.
- A comprehensive literature overview over co-opetition and related fields of economic sciences is given.
- An introduction into the relevant fields of strategic, cooperative and network games is provided.
- There is no theoretical foundation of co-opetition yet. Therefore the frame of further research is defined.

2

Development of a framework for co-opetition models

In this chapter, a framework for co-opetition models is developed by the author. A definition of co-opetition and determinants for co-opetition models are introduced. An industrial supply chain for co-opetition models is developed. The ubiquitous time-inconsistency of agreements is discussed. The “outside-option modified profit distribution rule for coalition structures” is developed. It is shown for models with mass markets in how far cooperative behaviour is stable. It is shown for models with individual customers, which profit distribution rules predicts the negotiation results of rational agents and assures the stability of an agreement.

2.1. Definition of co-opetition

Co-opetition is a perspective on business relationships that deals with the concurrency of competition and cooperation. Game theory is the appropriate mathematical instrument for formalized co-opetition models, giving the possibility of the prediction of the results of business strategies. In a co-opetition model a particular problem can be structured by a set of 5 determinants:

- institutions that determine the rules of business,

- industrial boundaries defined by
  - the products and/or services,
  - the transactions of products and/or services,
  - the industrial supply chains, which are a part of the global social network and
- time (1-round vs. many round games).

These 5 determinants allow a comprehensive description of a problem that is connected with business strategy. The business rule determining institutions are externally given, while the boundaries can be influenced by the agents. The time determinant allows round-based games.

Important institutions that determine the rules of business are contracts, states, culture and trade usages. Contracts are fixed in civil law and must be enforceable by the state, represented by a court of law. Large numbers of people are subsumed to groups of a certain culture that is characterized by common origin, ethnicity, religion, social status or age. Rules that are prevalent in such groups have been emerged often over a very long time and are usually fixed. Trade usages are important systems of business rules in particular regions, industries, vocations.

Industrial boundaries that are connected with the product or service refer to

- the content or
- the distribution (or transaction).

The content refers to:

- the value,
- the properties,
- the technology, etc.

The distribution (or transaction) refers to

- the place and
- the technology.

Distribution is usually restricted by

- political or cultural borders,
- language barriers,
- certain target groups,
- technology of distribution.

For instance products may be distributed only at the national market, in a region, city or at a certain place. In the European Union economic laws are widely harmonized. Nevertheless there are national and regional deviations like differences in taxation that are still trade obstacles. Furthermore, language barriers keep their relevance despite of economical globalization. Business is often restricted not to national borders, but language areas, e.g. English, Chinese, German or Lithuanian speaking countries. Target groups can be youths, pensioners, women, people with affinity to IT, etc.

Industrial boundaries also refer to the industrial supply chain. The agents are distinguished there as:

- suppliers, customers, competitors, "complementors" (offering complementary proposals),
- actual participators vs. potential participators and
- mass markets vs. individual customers.

Time is another crucial model determinant. Generally, each relationship or transaction is limited by time. Thus there is

- the static setting, where decisions are made uniquely and irrevocably (one round),
- the dynamic setting (at least 2 rounds),
  - with or without known end point and
  - with or without several possibilities to revoke formerly made decisions, e. g. by renegotiations

Many cooperative relationships have static setting. They are based on unique decisions, for instance simple purchases or the conclusion of projects, where the decision is irrevocable. Though they can also be extended over time, renegotiations or adjustments of formerly made decisions are not possible. In dynamic setting, renegotiations are possible and continuously lead to differing results. The circumstances permanently change, because of the continuously

- changing preferences of the agents,
- changing environment and
- information updating, etc.

This is the problem of time-inconsistency of agreements.

Figure 24 provides an overview over the co-opetition perspective, the set of co-opetition models and game theory as mathematical instrument:

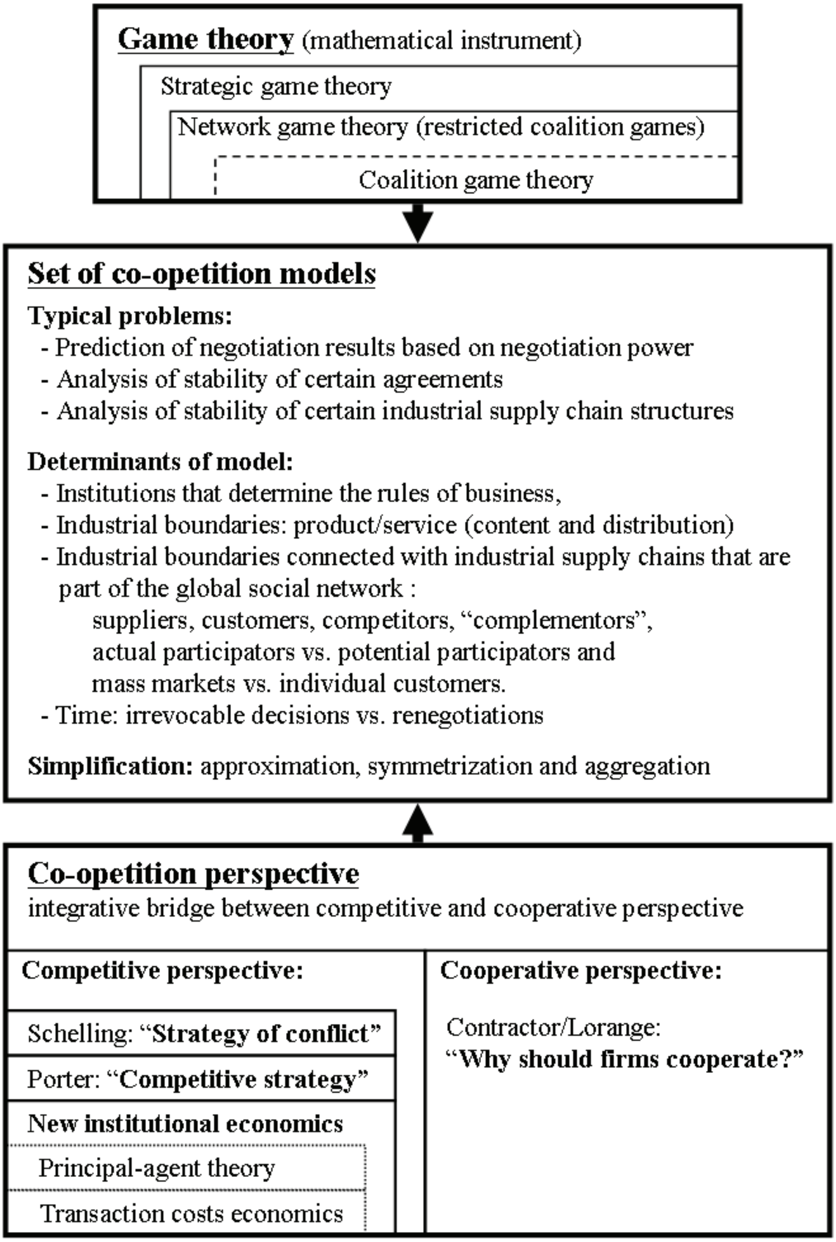


Fig. 24. Co-opetition perspective, set of co-opetition models and game theory as mathematical instrument (by the author)

Co-opetition as integrative bridge between the competitive and cooperative perspectives

In figure 24 it is shown that Schelling, Porter and the various contributors for the new institutional economics have emphasized on the competitive aspects of business relationships, while Contactor and Lorange's emphasized on cooperation. The co-opetition perspective is the integrative bridge between both perspectives.

Game theory as the mathematical instrument for the co-opetition models

Game theory is the appropriate mathematical tool for co-opetition models (Šelih et al. 2008), providing

- optimal decisions and strategies without and with agreements,
- the understanding of negotiations,
- the understanding of stability, Pareto-efficiency and fairness of agreements, etc.

for different settings of institutions, goods, transactions of goods, agents and time.

2.2. Industrial supply chain as part of a co-opetition model

2.2.1. Global social network

Following Milgram (1967) all agents are at least indirectly connected. This yields the "global social network" that is the superset of all social networks. A social network is a social structure made of nodes that usually represent individual persons, business agents like enterprises, etc. These are tied by specific types of interdependencies such as friendship, kinship, value, ideas, ideologies, trade, conflict, etc. (Vega-Redondo 2007) The ties or relationships that connect a certain node with other ones determine its role in the network. The resulting structures are depicted by graphs and are often very complex. The number and the strength of links are an important source of power.

The minimal number of links that connect two agents cannot be very high. Though the world population is estimated at 6.89 billion people (US Census Bureau, 1/2011), the small world phenomenon states that each social actor is not more than six persons away from each other social actor (Milgram 1967). That phenomenon is also termed "six degrees of separation". Hence, each regarded network, whether private or business related, is only an excerpt from the global social network. Each person on earth is a potential customer, supplier, "complementor" or competitor.

Figure 25 shows an excerpt of the global social network with an agent that is dominant by having a high amount of links, e. g. an enterprise having many suppliers.

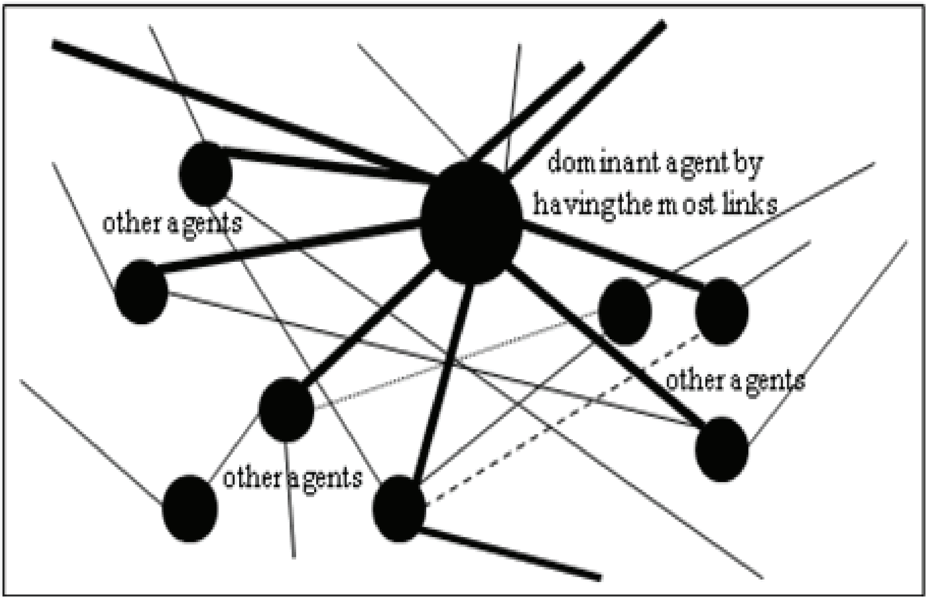


Fig. 25. Excerpt of global social network, agents with bilateral links and a dominant agent (with many links) (by the author)

2.2.2. The industrial supply chain as basis for co-opetition relationships

The industrial supply chain with co-opetition relationships is introduced by the author (Stein, Ginevičius 2010a). It is an excerpt of the global social network, as well. In an industrial supply chain, each relationship contains "win-win" and "win-lose" properties. An enterprise is officially connected with its suppliers, demanders and "complementors" (agents that offer complementary goods or services) are through a "win-win"-relationship, i. e. they are cooperation partners.

Chapter 1.3.3.2 has given an overview over possible complementors, suppliers and customers. Complementors can be strategic alliances, inter-industrial relationships, enterprises that have a joint venture, consortia, enterprises with renting, leasing, licensing relationships, employees, managers, etc.

On the other side competitors are connected through a “win-lose” relationship. However, in general also competitors have potentials to cooperate, for instance through

- open pricing cartels (as far as not prohibited),
- buying coalitions,
- tacit price collusions or
- by not attacking each other due to the threat of retaliation (TIT-FOR-TAT models) (Axelrod 1984).

This ambivalence of competition and cooperation is the main idea of co-opetition.

Figure 26 shows the “industrial supply chain with co-opetition relationships”. It depicts an enterprise in the relationship with other enterprises in the business environment and is advancement of Porter’s “5 forces driving competition” and of B/N’s “value net”. It shows next to the

- relationships with the actually participating agents (with the suppliers, customers, competitors and complementors)
- the potentially participating agents.

The potentially participating agents have the possibility of entering the game and therefore are strategically relevant. Due to the fact that an industrial supply chain may consist of several steps, it can be distinguished between retailers (possibly a chain of retailers) and end-customers on the one side, and on the other side between suppliers, pre-suppliers, etc. The end customers can be aggregated, i.e. they represent mass markets. The individual agents may also represent more than one agent, if they symbolize a coalition or network. Coalitions and networks can be depicted as individual agents that talk “with one voice” or decide monolithically (Wiese 2005). Individual customers and mass markets are treated in different ways:

- With individual customers it is possible to negotiate.
- With aggregated customers (mass markets), individual negotiations are impossible or too costly (transaction costs) in relation to the values of the single deals. Instead, a supplier concludes “a large number of single contracts” with customers. He anticipates the customers’ reactions and decides on that basis, according to backward induction.

The connection among competitors is depicted with a dotted line and depicts a possible cartel or tacit collusion.

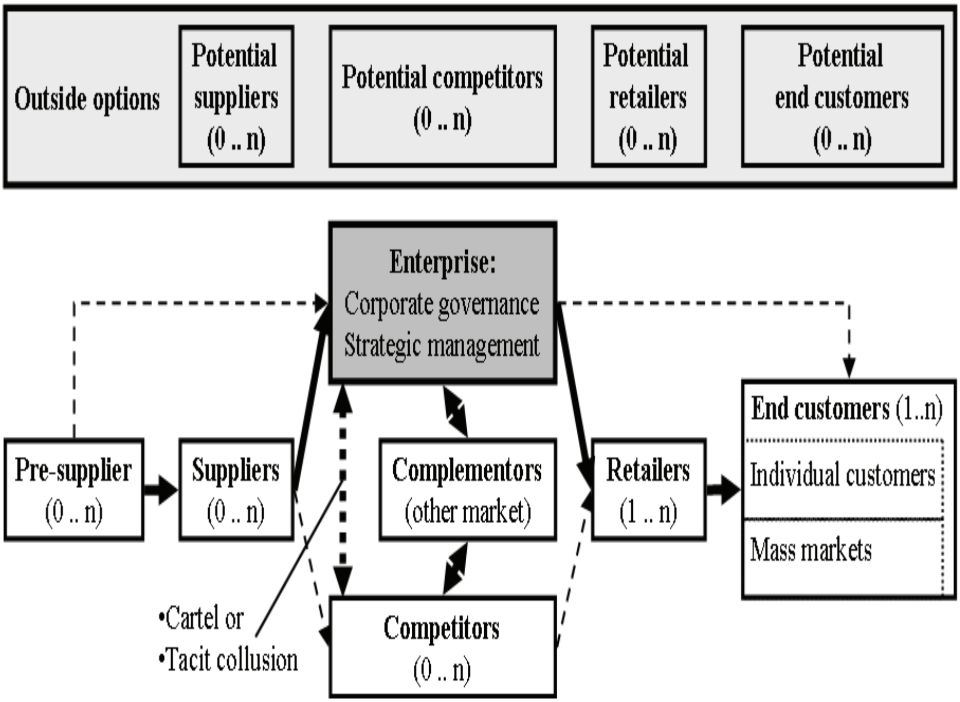


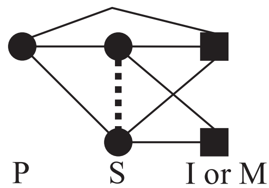
Fig. 26. "Industrial supply chain with co-opetition relationships" among suppliers, competitors, "complementors" and customers that are either individuals or mass markets and potential participants as outside options (by the author)

2.2.3. Supply chains with 3 agents

Due to the tremendous increase of complexity (Pin, 2005), it is important to keep the number of agents in the model low. Therefore, the author focuses on and lists the networks with not more than 3 agents.

3 agents can build supply chains in several ways. The supply chains can be of 2 stages (supplier - customer) or 3 stages (pre-supplier-supplier-customer). In 2-stage supply chains the suppliers can be competitors or complementors. The customers can be individuals or aggregated (mass markets). Figure 27 shows the set all possible supply chains with 3 agents. The labeling of the agents is ideal-typical. The meaning of "pre-suppliers" and "suppliers" are in so far different from that is the previous chapter that these are the last and penultimate steps before the customers.

Set of all 3 agents' supply chains



P: Pre-supplier
S: Supplier
I: Individual customer
M: Mass market

Fig. 27. Set of all supply chains with 3 agents, with individual customers or mass markets

The possible supply chains can be subdivided into those where there are:

- mass markets as customers,
- an individual customer, an suppliers and a pre-supplier and
- individual customers and suppliers.

In the next chapters mass markets are depicted by rectangles and individual customers are depicted by squares.

2.2.3.1. Mass markets as customers

There are 6 kinds of 3-agents' supply chains with suppliers, possible pre-suppliers and at least one mass market. In the following list (a.-f.) it is shown, which game theoretic methods are used to calculate the profit distributions.

a. 2 connected suppliers, 1 mass market

There are 2 suppliers that offer complementary goods to a mass market. They anticipate the mass market reaction in accordance to the principle of backward-induction (BI). Each supplier is able to profit by supplying the market at his own. However each of them profits if the other one supplies as well. If the suppliers intend to make an agreement among each other, they have to compare the profits they get without the other one with the profit that is achieved through common supply.

For instance, supplier S1 earns by supplying the mass market M 10 units. Supplier S2 proposes S1 to cooperate. For S1 it is not relevant whether S2 can make profit by supplying M at his own. Just the added value is relevant that is achieved by to cooperation between S1 and S1. This and only this added value is distributed equally between S1 and S2 in accordance to

- Myerson's axiom of balanced contributions and

– the axiom of Pareto-efficiency.

I. e. if the added value is 1 unit, S1 earns 10.5 units and S2 0.5 units. If the added value is 10 units, then it is (15; 5), etc. Thus, this profit distribution is in accordance with the principle of the Shapley-rule though it is used for the profit distribution among 2 agents.

b. 2 non-connected suppliers, 1 mass market

There are 2 suppliers that offer competitive goods to a mass market. This case is in accordance with the neo-classical model, where the potential suppliers anticipate the demand curve of the mass market. It is the distinction between Cournot quantity competition and Bertrand price competition (see chapter 1.4.1.3). In both cases BI is implemented, as the mass market's reaction is anticipated as the basis of the quantity or price competition among the suppliers.

c. 1 supplier, 2 mass markets

There is one monopolistic supplier who serves two mass markets. These are two separate transactions, and the BI's are made separately. The two mass markets do not affect each other as long as capacity restrictions are not considered. However, capacity restrictions are not investigated. These are solved by methods of convex optimization, like the Kuhn-Tucker optimization conditions (Avrieli 2003).

d. 1 supplier, 1 mass market, 1 individual customer

1 supplier serves both 1 mass market and 1 individual customer. As in the previous case, these are two separate transactions. BI is used for the mass market. With the single customer, the added value is distributed equally. Capacity restrictions are not considered.

e. 1 pre-supplier, 1 supplier, 1 mass market

1 pre-supplier and 1 supplier are vertically connected and serve 1 mass market. Both the pre-supplier and the supplier are indispensible in order to achieve any profit through the supplement of the mass market. Both of them anticipate the mass market's reaction (BI). The profit is distributed equally.

f. 1 pre-supplier, 1 supplier, 1 mass market (also direct connection between pre-supplier and mass market)

All agents are linked. The pre-supplier and the supplier directly serve the mass market and anticipate its reaction (BI). The pre-supplier can supply the mass market at his own. However he profits of the supplier's participation. The supplier might be a retailer. The added value is distributed equally.

Figure 28 shows all possible supply chains with mass markets and their bilateral relationships (links). Additionally the profit distribution is explicated shortly.

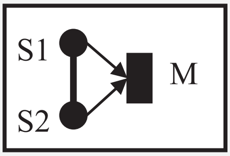
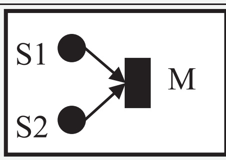
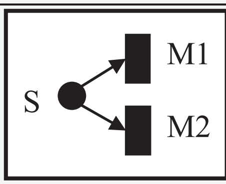
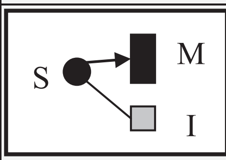
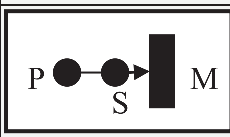
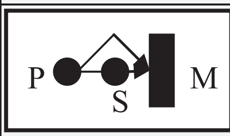
Connections		Network	Profit distribution
a.	S1 – M1 S2 – M1 S1 – S2		S1 and S2 anticipate M's reaction (BI). Based on this anticipation, they cooperate and distribute the added value of cooperating equally. However each of them keeps the profit that he would gain singly.
b.	S1 – M1 S2 – M1		S1 and S2 anticipate M's reaction (BI). The suppliers cannot cooperate. In dependence of whether it is quantity or price competition, it is the classical case of Cournot-equilibrium or Bertrand-equilibrium.
c.	S1 – M1 S1 – M2		S anticipates M1's and M2's reactions (BI). S is a unilateral (or monopolistic) decider. As long as there are no capacity restrictions, the decisions for M1 and M2 are completely independent. Otherwise it is distributed in accordance with profit maximization.
d.	S1 – M1 S1 – I1		P anticipates the reaction of M and supplies it as monopolist. Independent of that it supplies the individual customer. Without capacity restrictions, the profit is divided equally between S and I.
e.	P1 – S1 S1 – M1		P and S anticipate M's reaction (BI). As none of them is able to trade with M singly, they depend on each other completely, and divide the common profit equally.
f.	P1 – S1 S1 – M1 P1 – M1		P and S anticipate M's reaction (BI). P can supply M separately and S cannot. However S has the possibility to increase the total profit. This added value of S's participation is divided equally between P and S.

Fig. 28. All possibilities with maximally 2 agents and a mass market (by the author)

The possible unrestricted and restricted coalition structures for 3 agents' industrial supply chains are shown in appendix A, figure 2A. Neglecting the possible problem of capacity restrictions, the cases c. – f. can be decomposed into the following "trivial sub-networks" in figure 29:

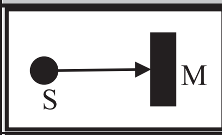
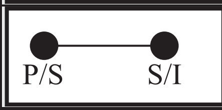
Connections	Network	Profit distribution
S – M		Unilateral backward induction
P – S		Equal distribution

Fig. 29. "Trivial sub-networks" that are sufficient to describe the networks c. – f. in figure 28 (by the author)

Therefore, only the cases a. and b. of figure 28 are considered further investigation.

2.2.3.2. Individual customer, supplier and pre-supplier

The 3-stage supply chains (with a pre-supplier and a supplier) are of a structure that might be deceptive at the "first impression". There are the cases that the

- pre-supplier is connected with the supplier and the supplier is connected with the customer and the case that,
- all agents are connected with each other.

Coalition structures are shown as far as they are relevant. "Relevance" requires that the pre-supplier and the individual customer are connected in one component.

a. 1 pre-supplier, 1 supplier, 1 customer, pre-supplier and customer not directly connected

In opposite to the "intuition", this case represents the grand coalition, as no agent is able to gain any profit without the participation of the other both agents. None of the agents can earn anything without the participation of the other ones. Therefore the division is in accordance with the Shapley-rule and is equal (referring to eq. 2.22):

$$Shapley-value=\left(\frac{1}{3};\frac{1}{3};\frac{1}{3}\right) \tag{3.1}$$

b. 1 pre-supplier, 1 supplier, 1 customer, pre-supplier and customer directly connected

It might be the "first impression" that this structure represents a grand coalition. However, these are 2 overlapping games, which are summarized:

1. The pre-supplier and the end customer divide their added value equally.
2. The supplier is not inevitable but offers added value to both the pre-supplier and the end customer. For instance, it can be a retailer that is located "around the corner" next to the end customer while the pre-supplier organizes his transactions on the basis of electronic business (i. e. uses the internet). This added value is achieved in equal parts by all 3 agents. It is equivalent with the grand coalition of case a. Therefore it is the division:

$$Shapley-value=\left(\frac{1}{3};\frac{1}{3};\frac{1}{3}\right) \tag{3.2}$$

For instance, if in the first game the added value is 80 units and in the second game it is 90 units, then the profit distribution is:

$$(P;S;I)=(40;0;40)+(30;30;30)=(70;30;70) \tag{3.3}$$

For instance, if in the first game the added value is 80 units and in the second game it is 90 units, then the profit distribution is:

$$(P;S;I)=(40;0;40)+(30;30;30)=(70;30;70) \tag{3.3}$$

If there is the coalition structure where the pre-supplier and the end customer are connected within a component, the supplier is excluded. The first game is implemented, where the profit is distributed equally between the pre-supplier and the end customer. This corresponds with the ADMCS-rule:

$$ADMCS-rule=\left(\frac{1}{2};0;\frac{1}{2}\right) \tag{3.4}$$

Figure 30 shows both supply chains and the coalition structure of case b. The profit divisions are listed shortly:

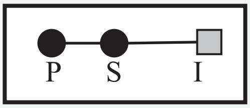
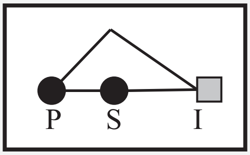
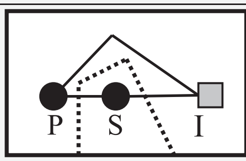
Connections		Supply chain	Profit division
a.	P – S S – I		In opposite to the presumable "first impression", this is the case of the **grand coalition**. No agent can achieve any added value without the other ones. Therefore the Shapley-rule is used: $Shapley = \left(\frac{1}{3};\frac{1}{3};\frac{1}{3}\right)$
b.	P – I P – S S – I		**2 overlapping games**: 1. P and I distribute their added value equally. 2. Grand coalition, the added value that is achieved by the S is distributed: $Shapley-value(P;S;I) = \left(\frac{1}{3};\frac{1}{3};\frac{1}{3}\right)$
	Coalition structure: P – I Excluded: S		Just 1st game relevant, P and I equally distribute their added value. S is excluded. $Aumann-Drèze-value(P;S;I) = \left(\frac{1}{2};0;\frac{1}{2}\right)$

Fig. 30. All possibilities of supply chains and coalition structures with 3 agents (by the author)

Case a. can be regarded as a trivial sub-network. The grand coalition of case b is the sum of case a. and the 2nd trivial sub-network of figure 29. Therefore all networks of figure 30 are excluded from further investigation.

2.2.3.3. Two stage supply chains with individual customers

In 2-stage supply chains there are 2 cases of grand coalitions:

- The suppliers are directly connected.
- The suppliers are not directly connected.

Again, the coalition structures are only listed if they are "relevant", i. e. the supplier is in one component with the individual customer.

a. 2 connected suppliers and 1 individual customer

In the grand coalition, the suppliers are potential complementors. They may profit by cooperating in comparison with supplying on their own. In the case that a stable grand coalition is formed, it is calculated with the Shapley-rule. The relative profit of the suppliers cannot be predicted in general. However the customer gains half of the profit, as it is indispensible in the supply chain. Both suppliers gain the other half together, due to the fact that at least one of them has to be in the game. Therefore the Shapley-rule is used with the following structure:

$$Shapley-value(S_1;S_2;I)=\left(share;1-share;\frac{1}{2}\right) \text{ with } share\in\left[0..\frac{1}{2}\right] \quad (3.5)$$

The variable $share$ is referred to the share of the residual ½ among the both suppliers. It depends on their contributions to the added value of the grand coalition.

In the coalition structure of case a., the supplier 1 is directly connected with the individual customer. The second supplier is excluded from the “productive component”. For this case the ADMCS-rule proposes the “simple” solution that ignores the possible impact of the excluded supplier.

b. 2 non-connected suppliers and 1 individual customer

In the restricted grand coalition, the suppliers that are competitors and cannot make a direct agreement. In the case that a stable restricted grand coalition is formed, it is calculated with the Myerson-rule with $g=\{I\_S_1;I\_S_2\}$.

$$Myerson-rule(S_1;S_2;I)=\left(share;1-share;\frac{1}{2}\right) \text{ with } share\in\left[0..\frac{1}{2}\right] \quad (3.6)$$

If no stable restricted grand coalition is possible, it is identical with case a. Figure 31 shows the cases a. and b., i. e. the (restricted) grand coalitions and the (restricted) coalition structures:

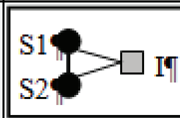
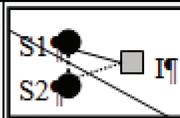
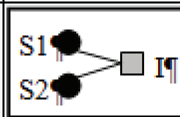
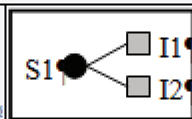
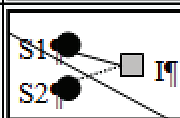
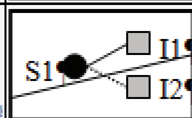
Connections			Supply chain		Solution
a.	Grand coalition	S1 – S2 S1 – I1 S2 – I1			Shapley-rule
	Coalition structure	S1 – I1 Excluded: S2			**No sufficient solution yet**
b.	Restricted grand coalition	S1 – I1 S2 – I1 (equivalent: S1–I1; S1–I2)			Myerson-rule
	Coalition structure	S1 – I1 S2 excluded (equivalent: I2 excluded)			**No sufficient solution yet**

Fig. 31. 2-stage supply chains, coalition structures with individual customers (by the author)

There are 5 other coalition structures for games with 3 individual agents that are not relevant for supply chains, because the first and the last agent in the chain are not in one component. These are depicted in appendix A, figure 2A.

The development of the new profit distribution rule that is made in chapter 2.4 refers to the coalition structures of figure 31. It is considered as an alternative to the ADMCS-rule, where the possible impact of the excluded agent is considered.

2.2.4. Comparison with 2 and 4 agents' supply chains

Appendix B shows all combinations of supply chains with 2 agents (figure 1B) and 4 agents (figures 2B and 3B). While the possibilities for 2 agents are very limited, the number of combinations increases tremendously in supply chains with 4 agents. The set of supply chains with 4 agents is the superset of supply chains with 3 agents, and a subset of the global social network.

In table 10 the number of grand coalitions, coalition structures and both in the restricted cases are compared for 2, 3 and 4 agents, with only individual customers. Furthermore the combinations with mass markets are listed. These are summarized in appendix B, table 1A. The tremendous increase of combinations with each additional agent is depicted.

Table 10. Number of possible supply chains and coalition structures with individual customers with 2, 3 and 4 agents (by the author)

Supply chain relevant networks	2 agents	3 agents	4 agents
Grand coalitions	1	2	6
Coalition structures	-	2	19
Restricted grand coalitions	-	3	25
Restricted coalition structures	-	2	60
Combinations with mass markets			
Grand coalitions	1	2	12
Coalition structures	-	2	40
Restricted grand coalitions	-	4	56
Restricted coalition structures	-	3	137

In the thesis only the cases of 3 individual agents and of 2 individual agents with a mass market in a grand coalition are regarded, because it allows far-reaching possibilities for co-opetition models while keeping complexity “appropriate”. Co-opetition models with 4 agents are thinkable. However, the tremendous increase of possible networks confirms that network games are in the complexity class “NP-hard” (chapter 1.2).

2.3. Ubiquity of time-inconsistency of agreements

A comprehensive overview over the reasons for the time-inconsistency of agreements is given by the author. Time-inconsistency is ubiquitous in agreements. After an agreement is made, circumstances change continuously and at least one of the participating agents becomes dissatisfied. However the agreement remains stable as long as there is no beneficial alternative, an outside option. There are 2 main origins of the time-inconsistency of agreements:

- acquirement of skills and
- information updating.

The acquisition of skills is in general unilateral. An agent copes with a task better over the time. This can increase the value of his work. In the new institutional economics, the professional skills are regarded as “human capital”. If an agent improves his skills, also the cooperation partner should gain from that.

Information updating is directly crucial for the rational decisions as they are based on available information (Rutkauskas, Ramanauskas 2009). An agent may have the information input

- before the agreement conclusion or
- after the agreement conclusion.

All events in the information that the agent receives before the agreement conclusion, are “expected events”. All other events are unknown till the moment when the information updating takes place. These are “unexpected events”. In general, there are future events that are unexpected. Here, the simplified special case is regarded as well, where all future events are known. Then all information can be considered, before the contract is concluded at the beginning.

Information updating may refer to

- general environment information,
- the relationship or the relationship towards other agents or
- oneself.

The general environment information may refer to

- force majeure,
- change in the global social network: politics, laws, etc.
- change in the larger local networks.

Relationship related learning is particularly important in games with private information. Other agents may hide information or their real preferences. They may obtain new information or their preferences may change. The revelation of information by other agents may take place voluntarily or involuntarily. If it is involuntarily, it has been forced

- before the agreement conclusion by screening or
- or after the agreement conclusion by monitoring (Göbel 2002).

Learning can be connected with oneself. Even if there are no external impulses one’s own preferences may change, and thus the assessment of the agreement.

Figure 32 give a comprehensive overview over the reasons for the time-inconsistency of agreements.

Reliance is crucial in business relationships. However reliance is barely quantifiable as it is questionable, whether the signals of loyalty can be interpreted unanimously. Furthermore, it is barely possible to predict the development of reliance as it is a subjective attempt to predict the other agents’ behaviour. The agents mutually increase reliance through the signalling of loyalty. The history of fulfilled commitments is the basis of reliance as they are the most important signal of loyalty. Not fulfilled expectations or commitments may destroy reliance.

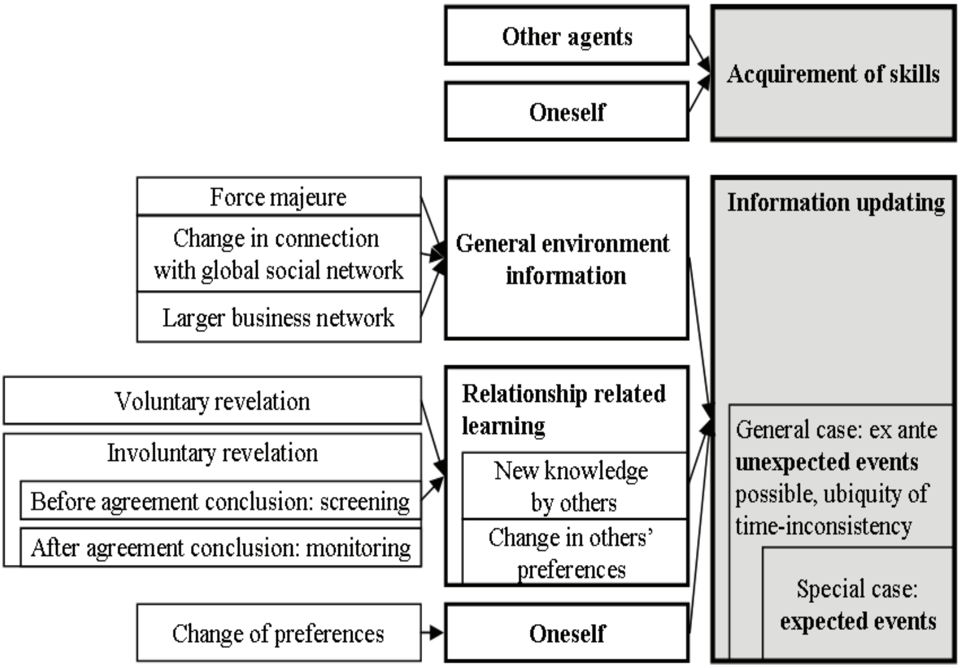


Fig. 32. Reasons for the time-inconsistency of agreements (by the author)

For the sake of simplicity it is assumed that there is sufficient reliance among cooperating agents in order to cooperate. A detailed analysis is omitted.

2.4. Development of an profit distribution rule for coalition structures with outside option

2.4.1. Introduction of the “OOCS-rule”

A new profit distribution rule is developed by the author that considers the outside option, i.e. the impact of the excluded agent on the relationship of the 2 cooperating agents in the case of an unbalanced 3 agent network. An exemplary network is shown in figure 33 where a principal has the choice between 2 suppliers:

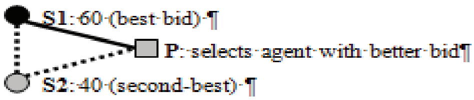
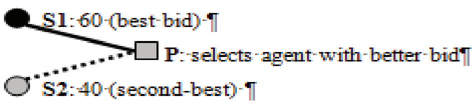
Network	Characteristic (network) function
	$v = \{0;0;0;60;40;0;0\}$
	$v_g = \begin{cases} 0; \lvert agents \rvert \le 1 \\ 60; g = \{S_1;P\} \\ 40; g = \{S_2;P\} \\ 0; g = \{\{S_1;P\};\{S_2;P\}\} \end{cases}$

Fig. 33. Coalition structure in unrestricted and restricted 3 agents' network

The situation is assumed, where a principal is looking for a supplier and wants to select exactly one supplier, because more than one would lead to inappropriately high administration costs. The suppliers compete in an auction procedure. They iteratively "improve" their bids, until 2 of them remain in the auction. This is depicted by the 3-agents'-network. The 2 suppliers overbid each other and approach the reservation bid (maximal bid) of the 2nd best supplier. As soon as the supplier with the best bid makes a higher bid, the 2nd best supplier leaves the auction. Thus, the reservation bid of the 2nd best supplier becomes public information (Steimle, 2008). The agreement between the principal and the strongest bidder cannot be blocked any more.

For the sake of simplicity it is assumed here, that the strongest supplier reveals his real reservation bid. For instance, he assumes that the principal is going to find it out has the power to update the agreement in a way, that there is no incentive to cheat. The best and the 2nd best bids are public information. The principal regards the difference between the best and the 2nd-best bid as the added value of the best supplier. This added value is divided symmetrically, i. e. equally. This is the idea of the:

Outside-option modified profit distribution rule for coalition structures (OOCS-rule)

Similar to Myerson's axiomatization of the Shapley-rule (Myerson, 1980), the OOCS-rule is defined by the axioms:

- Component-Pareto-efficiency: $\sum_{i \in C} OOCS(N, v, g) = v(C)$ for the productive component (3.7)
- Modified axiom of balanced contributions:

The modification of the axiom of balanced contributions consists of a pre-stage, where the winning cooperation partner transfers the value of the loosing cooperation partner to the main agent. Afterwards the balanced contributions axiom is used in the usual way. Thus:

- For the agents $A, B, C \in N$: if A has to select the cooperation partner and $v(AB) > v(AC)$, then A selects B and first demands the amount: $v(AC)$ by agent B. (3.8)
- Afterwards the contributions are balanced:

$$OOCS_A(N, v, g) - OOCS_A(N, v, g \setminus \{B\}) = OOCS_B(N, v, g) - OOCS_B(N, v, g \setminus \{A\}) \quad \text{... (3.9)}$$

- So that A and B divide the difference of B's and C's offer equally.

In a coalition structure (Stein, 2010a), with A and B in the "productive component" and C and the outside option for A, the OOCS-rule provides for $v(AB) > v(AC)$:

$$OOCS - rule = \left(\frac{v(AB) + v(AC)}{2}; \frac{v(AB) - v(AC)}{2}; 0 \right) \tag{3.10}$$

In comparison, the ADMCS-rule provides (eq. 2.30):

$$ADMCS - rule = \left(\frac{v(AB)}{2}; \frac{v(AB)}{2}; 0 \right) \tag{3.11}$$

A profit distribution in accordance with the OOCS-rule does not depend on super-ordinate institution (i. e. the state) for the assertion of the agreement (in a game with coalition structure). It cannot be blocked by any other sub-group of agent. Therefore it is a strong equilibrium (Aumann 1961) and hence and CPNE. The CPNE does not require the mutual assumption of the other agents' rationality.

2.4.2. Net present values and the characteristic function

In order to compare the values of alternatives in dynamic setting, the net present values are regarded. A round-based dynamic setting is considered where the present values PV of each period are discounted and summarized. The present value provides for each point in time the added value of selecting the alternative compared with not selecting it: $PV_t = (profit_t - \cos ts_t)$.

The net present value is:

$$NPV_\tau = \sum_{t=\tau}^{T} (profit_\tau - \cos ts_\tau) \times \frac{1}{(1+r)^\tau} = \sum_{i=\tau}^{T} (PV_\tau) \times \frac{1}{(1+r)^\tau} \tag{3.12}$$

As the static setting is a special case of the dynamic setting, the NPV's are valid as well. Net present values can be used as "input" for the characteristic network function, as they provide a single profit value for a certain alternative:

$$v(P, S_1) = NPV_{P;1} \;;\; v(P, S_2) = NPV_{P;2} \tag{3.13}$$

Table 11 shows the minimal and the maximal bids out of the perspectives of the best and 2nd-best supplier, in dependence of which of them offers the higher NPV for the principal:

Table 11. Minimal, maximal bids of the suppliers in dependence of the NPV's (by the author)

Perspective of supplier	NPV's of principal	Minimal bids	Maximal bids	OOCS $(P;S_1;S_2)$
S_1	$NPV_1 > NPV_2$	$NPV_2 + x$	NPV_1	(1) $\left(\frac{NPV_1 + NPV_2}{2}; \frac{NPV_1 - NPV_2}{2}; 0\right)$
	$NPV_1 < NPV_2$	NPV_1		(2)
S_2	$NPV_2 > NPV_1$	$NPV_1 + x$	NPV_2	(2) $\left(\frac{NPV_2 + NPV_1}{2}; 0; \frac{NPV_2 - NPV_1}{2}\right)$
	$NPV_2 < NPV_1$	NPV_2		(1)
S_1 or S_2	$NPV_1 = NPV_2$	$NPV_1 = NPV_2$		$(NPV;0;0)$

The table 10 is explicated here from the perspective of supplier 1. The perspective of supplier 2 is just mirror-inverted. If the NPV of the principal that is achieved by the cooperation with supplier 1 (NPV_1) is higher than that of the cooperation with 2, supplier 1's minimal bid exceeds NPV_2 marginally. x is a marginally small value, e. g. 1 Euro-cent. In that case, the principal earns not more than the NPV_2, and the supplier 1 earns his complete added value. The maximal bid of supplier 1 is the complete NPV. In that case, supplier 1 does not gain anything, and the principal gains everything. According to the OOCS-rule, the principal gains the complete NPV_2 and additionally the half of the added value that is provided by supplier 1,

$$NPV_2 + \frac{NPV_1 - NPV_2}{2} = \frac{NPV_1 + NPV_2}{2}. \tag{3.14}$$

Supplier 1 also gains the half of the added value but not more than that, i. e. $\frac{NPV_1 - NPV_2}{2}$. The case that the NPV's of both suppliers are equal is the most advantageous one for the principal. Then the principal gains everything and the both suppliers do not gain anything.

Table 12 shows different characteristic functions with the according NPV's, minimal and maximal bids of the suppliers, the OOCS-rules and the differences of the outcomes for the principal:

Table 12. Minimal, maximal payments, the "outside-option modified profit distribution rule for coalition structures (OOCS)" and the differences with step by step improving agent S_2 (by the author)

v	**NPV**		Min. bid of S_1 / S_2			Max. bid of S_1 / S_2			OOCS			Δ bids	
			P	S_1	S_2	P	S_1	S_2	P	S_1	S_2		
1	$NPV_{P;S_1}$	**20**	0.01	19.99		20	0		10	10		←	10
	$NPV_{P;S2}$	**0**	0		0	0		0	0		0		
2	$NPV_{P;S_1}$	**20**	10.01	9.99		20	0		15	5		←	5
	$NPV_{P;S2}$	**10**	10		0	10		0	10		0		
3	$NPV_{P;S_1}$	**20**	20	0		20	0		20	0		←	0
	$NPV_{P;S2}$	**20**	20		0	20		0	20		0	←	0
4	$NPV_{P;S_1}$	**20**	20	0		20	0		20	0			
	$NPV_{P;S2}$	**30**	20.01		9.99	30		0	25		5	←	-5
5	$NPV_{P;S_1}$	**20**	20	0		20	0		20	0			
	$NPV_{P;S2}$	**40**	20.01		19.99	40		0	30		10	←	-10

2.4.3. Comparison of the "OOCS-rule" with the Aumann-Drèze-rule / Myerson-rule for coalition structures for 3 agents

In table 13 the proposed OOCS-rule is compared with the ADMCS-rule. The characteristic functions of table 12 are taken. Additional steps are included as "interpolation":

Table 13. Comparison of the ADMCS-rule with the proposed OOCS-rule (by the author)

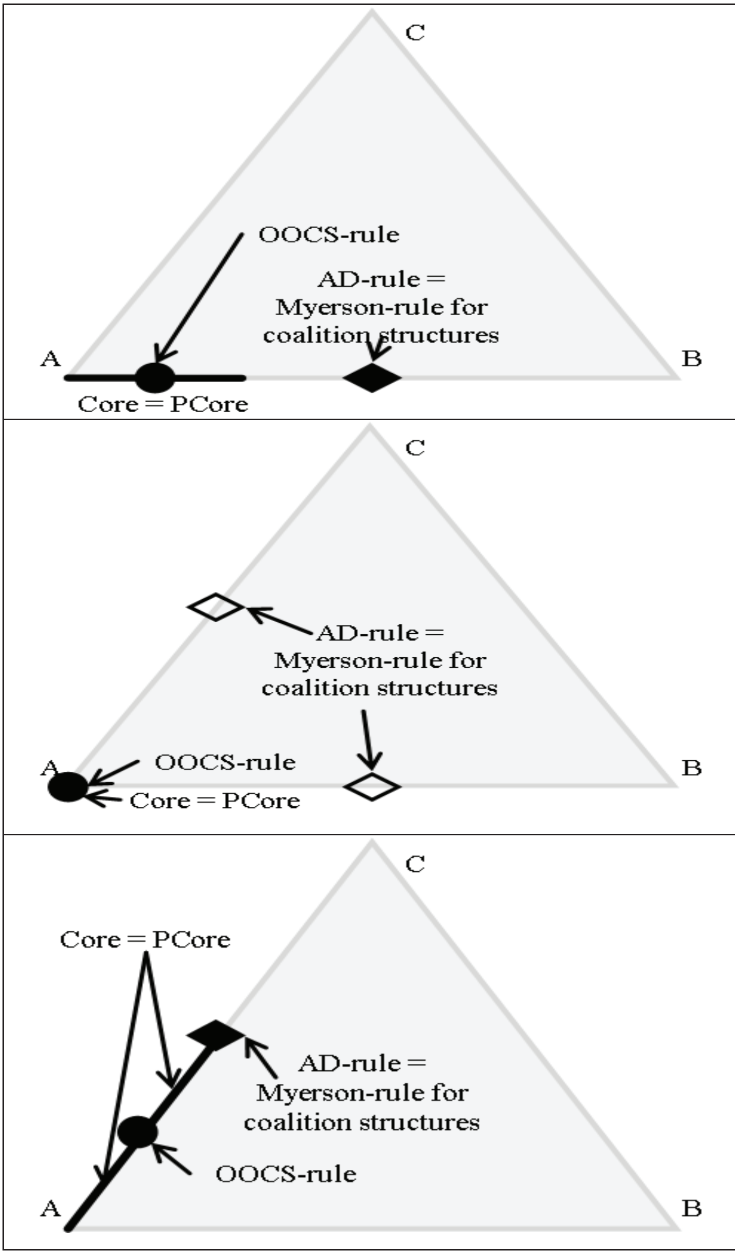
$v(P;S_1)=NPV_{P;S_1}$	$v(P;S_2)=NPV_{P;S_2}$	OOCS-rule	ADMCS-rule
20	0	(10, 10, 0)	(10, 10, 0)
20	5	(12.5, 7.5, 0)	(10, 10, 0)
20	10	(15, 5, 0)	(10, 10, 0)
20	15	(17.5, 2.5, 0)	(10, 10, 0)
20	**20**	(20, 0, 0)	(10, 10, 0) or (10, 0, 10)
20	**25**	(22.5, 0, 2.5)	(12.5, 0, 12.5)
20	**30**	(25, 0, 5)	(15, 0, 15)
20	**35**	(27.5, 0, 7.5)	(17.5, 0, 17.5)
20	**40**	(30, 0, 10)	(20, 0, 20)

In figure 34 the OOCS-rule and the ADMCS-rule are compared graphically on imputation sets. The minimal and maximal offers of the winning bidder (table 12) are both the end points of the respective edge-core. The OOCS-rule (and 2-agents' Shapley-rule) is the arithmetic average. This is the consequence of the introduced "modified axiom of balanced contributions".

On the left side, the NPV that is offered by supplier 1 is better that that of supplier 2. The ADMCS-rule completely ignores the bid of supplier 2 that is here the "outside option", and the NPV is divided by halves between the principal and the supplier 1. In opposite, the OOCS-rule considers supplier 2's bid. Furthermore the OOCS-rule lies inside the core or the PCore. Therefore it is stable against the offer of the outside option, being a CPNE.

In the middle image, the NPV's of both suppliers are identical. There are 2 ADMCS-rules, and the principal is indifferent between both suppliers. However none of these values is stable in the sense of the core / PCore. In opposite, the OOCS-rule is unique and equals the unique point of the core / PCore.

On the right side, supplier 2 offers a higher NPV. In this particular case, the ADMCS-rule is inside the core and therefore stable against the other sub-coalition. However the OOCS-rule is in the centre of the core / PCore and considers the outside option, the excluded supplier 1.



Characteristic function	
P; S1	20
P; S2	15
S1; S2	-
OOCS-rule	
A	17,5
B	2,5
C	0
ADMCS-rule	
A	10
B	10
C	0

Characteristic function			
P; S1	20		
P; S2	20		
S1; S2	-		
OOCS-rule			
A	20		
B	0		
C	0		
ADMCS-rule			
A	10	A	10
B	10	B	0
C	0	C	10

Characteristic function	
P; S1	20
P; S2	40
S1; S2	-
OOCS-rule	
A	30
B	0
C	10
ADMCS-rule	
A	20
B	0
C	20

Fig. 34. Core, PCore, ADMCS-rule and OOCS-rule if supplier 1 has better offer that supplier 2 (by the author)

Hence, the OOCS-rule has the following advantages in comparison with the ADMCS-rule:

- The OOCS-rule is unique while if both alternatives are equal, the ADMCS-rule has 2 solutions.
- The OOCS-rule considers the impact of the outside option while the ADMCS-rule provides 50%–50% divisions among the "productive component".
- While an agreement that is according to the ADMCS-rule is possibly broken immediately in dynamic setting, an OOCS-rule based agreement is stable in the sense of the core / PCore.
- The OOCS-rule does not require the mutual assumption of the other agents' rationality, while the ADMCS-rule requires.

2.4.4. The impact of private information on the deployment of the OOCS-rule

If the suppliers are able to hide their maximally possible bids, i.e. their reservation bids, the question of private information comes to the fore, which has been explicated in chapter 2.4.3.

As the result of the auction iteration, only the weaker supplier A_2 reveals his reservation bid. The weaker supplier does not profit by not revealing and continues the iteration, until his reservation bid is public information. In figure 35 it is 40. For the stronger agent it is generally advantageous not to reveal his offer (Vickrey 1961). Therefore he only exceeds S2's offer marginally. The principal may "speculate" on a higher reservation bid of S1, but this does not lead to S1's new revelation, as long as S1 does not expect the principal to discover his real reservation bid. This might change by the screening or monitoring by the principal. If S1 assumes that the screening or monitoring by the principal discovers his reservation bid, he does not have any more incentive to cheat. Then, the revelation of the reservation bid becomes incentive-compatible.

Another possibility for the principal to discover a higher reservation bid of the strongest supplier is to "speculate" and to give credible signals of expecting it. The possible situation of mutual bluffing is not delved here. In this case it is only restrictedly possible to predict the negotiation result, as the prediction depends on the public information. However, the relevance of the OOCS-rule is not affected. It is calculated on the basis of the revelations. Expenses for screening and monitoring cannot be transferred by the principal to a supplier. In figure 35 the case of fraud reservation bid yields the profit distribution:

$OOCS = (40;20;0)$. If S1 reveals his reservation bid correctly, it yields: $OOCS = (50;10;0)$.

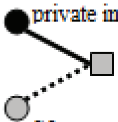
Network	**Fraud reservation bid revelation by S1:**	**Incentive-compatibility for S1 to reveal the real reservation bid** (e.g. S1 assumes monitoring by principal)
S1: best bid that remains private information  **P**: selects agent with better bid **S2**: second-best bid that becomes public information	$v_g = \begin{cases} 0; \lvert agents \rvert \le 1 \\ \text{"40.01"}; g = \{A_1;P\} \\ 40; g = \{A_2;P\} \\ 0; g = \{\{A_1;P\};\{A_2;P\}\} \end{cases}$	$v_g = \begin{cases} 0; \lvert agents \rvert \le 1 \\ \text{"60"}; g = \{A_1;P\} \\ 40; g = \{A_2;P\} \\ 0; g = \{\{A_1;P\};\{A_2;P\}\} \end{cases}$

Fig. 35. Coalition structure in 3 agents' network with private information, revelation of fraud reservation bid and real reservation bid by S1 (by the author)

2.5. Outcome and stability predictions for agreements in models with mass markets

The author comprehensively collects the outcome and stability predictions for agreements in models with mass markets. The mass market games that have the structure of the supply chains of figure 28 are not suitable for the use of the ADMCS-rule or the introduced OOCS-rule as profit distribution rules directly. Only 2 agents are individual deciders. The mass market itself just reacts on the decisions of the 2 suppliers who anticipate its reaction. Therefore the mass market games are by far less complex than games with 3 individual agents

However, the games with mass markets and with individual customers are similar, due to the fact that the intention of cooperation is to achieve a Pareto-efficient outcome. In both kinds of models, the "added value" is the difference between the outcome that is based on the completely mutually non-cooperative decisions and the actual outcomes. In the case of mass market games, the added value of cooperation is the difference of the "sum of the profits of both suppliers in the Cournot-Nash-equilibrium" and the "sum of the profits in the cartel solution". The Pareto-efficient solution that is comparable with the outcome that is recommended by "profit distribution rules" is the "cartel" and is generally the result of negotiation (chapter 1.4.1.4).

The major difference between the games with mass markets and games with individual customers refers to the stability of cooperation. Cartel solutions and any other solutions that contain “added value” are usually not stable against unilateral defections of one or both agents. They do not fulfill the criterion of being a coalition-proof Nash-equilibrium. Therefore, each supplier has the incentive to deviate from the cartel agreement and improving his own situation at the expense of the other one. Particularly the last round of a TIT-FOT-TAT model equals a one-round game. Therefore cooperation may break down at the end in accordance with the “end game effects” (chapter 1.4.1.5).

Nevertheless, there are certain reasons, why cooperative outcomes are “not completely unstable”. The TIT-FOT-TAT models contain the “threat of retaliation” which is the crucial incentive for not defecting from a cooperative solution. Furthermore, cultural institutions or trade usages (chapter 2.1) may facilitate that the negotiation outcome is “respected”.

In table 14, the stability of agreements among agent that supply a mass market is discussed.

Table 14. Discussion of the stability of cooperation in models with mass market customers, in dependence of the number of rounds and the possibility of negotiation (by the author)

<table>
<tr><th rowspan="3">Arguments for</th><th colspan="4">Model with 2 suppliers and a mass market</th></tr>
<tr><th colspan="2">Time: 1-round</th><th colspan="2">Time: more than one round</th></tr>
<tr><th>No negotiation</th><th>Negotiation possible</th><th>No negotiations</th><th>Negotiation possible</th></tr>
<tr><td rowspan="3">Stability: incentives to play cooperatively</td><td colspan="4">Wish to achieve Pareto-efficient outcome</td></tr>
<tr><td></td><td>Negotiation outcomes may be respected due to culture or trade usages</td><td></td><td>Negotiation outcomes may be respected due to culture or trade usages</td></tr>
<tr><td colspan="2"></td><td colspan="2">Threat of retaliation</td></tr>
<tr><td rowspan="4">Instability: incentives to play non-cooperatively</td><td colspan="4">Possibility to gain higher profit at the expense of the other agent</td></tr>
<tr><td colspan="2">No threat of retaliation</td><td colspan="2"></td></tr>
<tr><td>No communication possible</td><td></td><td>Communication only by the observation of previous rounds</td><td></td></tr>
<tr><td colspan="2"></td><td colspan="2">“End game effects”: equality with 1-round games in last round, due to the lack of threat of retaliation</td></tr>
</table>

Thereby the focus is on the contradictory incentives of playing cooperatively and non-cooperatively. It is distinguished between the following co-opetition models:

- One-round model without communication

- One-round model with communication, i.e. possibility of negotiation
- Many-round model without communication
- Many-round model with communication, possibility of negotiation.

2.6. Outcome and stability predictions for agreements in models with individual customers

2.6.1. The outcomes of negotiations and renegotiations

Now the author comprehensively develops the outcome and stability predictions of agreements in models with individual customers. Negotiations only take place in the relationship with individual agents. Therefore, the relationships with individual are generally by far more complex than "relationships" with mass markets. In general, the negotiation outcome is not predictable, as it does not only depend on the prerequisites of each agent, but also on his negotiation skills, or whether he is in a good shape, etc. Nevertheless, profit distribution rules provide a prediction about how the outcome would look like, if each agent was a "tough negotiator", fulfilling the ideal of the (intended but bounded) rational decider. The successful negotiation leads to an agreement that may contain:

- Mutual commitments and obligations,
- Duration,
- Profit distribution.
- Contractual punishments (for the case that one partner breaks the agreement).

If renegotiations take place, they may refer to

- the switch of the cooperation partner or
- the change of the profit distribution among the partners.

The 3 agents' network with 2 suppliers and the principal is regarded. The agent (supplier) who is outside the "productive component" is excluded and represents the outside option. The cases are compared whether

- Renegotiations are not possible (static models),
- Renegotiations are possible (dynamic models): Agent switching costs high (not possible),
- Renegotiations are possible (dynamic models): Agent switching costs low (possible).

If renegotiations are not possible, the decision is unique and irrevocable. Even if the project takes place over a certain time, the model is static. There is

"1 round". If renegotiations are possible, the model is dynamic. In this case, the decisions are made on the basis of the residual net present values.

2.6.2. Static models: profit distribution rules for stable agreements

In the case that renegotiations are not possible the agents make a unique decision and implement the agreement over the whole period of the agreement. For instance, an enterprise selects its enterprise resource planning software (chapter 2.3.3). The decision may affect the business processes in the company for more than one decade. However, the decision is unique and neither the agreement partners nor the profit division are revocable. Therefore it is a static model. In a static game with coalition structures, where there are 3 agents and 1 excluded agent, the OOCS-rule is appropriate. As shown in chapter 2.4.3, the OOCS-rule is advantageous towards the ADMCS-rule because:

- it considers the impact of the excluded agent, i.e. the outside-option and
- is stable in the sense of the coalition-proof Nash-equilibrium (chapter 1.4.1.6)

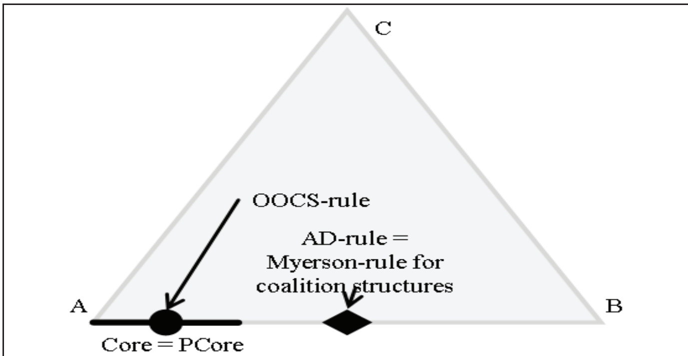
The ADMCS-rule is not stable against a subgroup blocking that is initiated by the excluded agent.

For games with grand coalitions, the profit distribution rules are

- the Shapley-rule (unrestricted characteristic function) or
- the Myerson-rule (restricted characteristic function)

respectively. If the characteristic function is balanced but not convex, there exists a stable (restricted or unrestricted) grand coalition, but the Shapley-rule and the Myerson-rule do not yield a stable allocation. If the characteristic function is unbalanced, coalition structures inevitably emerge.

In figure 36 the characteristic function from figure 34 (left) is taken with the assumption that all information is public. It is expected that the average empirical negotiation results coincide with the OOCS-rule and not with the ADMCS-rule, being the result of the auction procedure (chapter 3.4). However, as the negotiation result is in general not determinable, a certain small deviation ε with $\varepsilon_P = \varepsilon_{S1} + \varepsilon_{S2}$ is possible, as long as the allocation remains in the core or PCore, i. e. being a CPNE (chapter 1.4.1.6).



Coalition values	
AB	**20**
AC	15
BC	0
ABC	**0**

Assumed average of empirical results			**OOCS-rule**			**ADMCS-rule**		
P	S_1	S_2	P	S_1	S_2	P	S_1	S_2
$17.5-\varepsilon_P$	$2.5+\varepsilon_{S1}$	$0+\varepsilon_{S2}$	17.5	2.5	0	10	10	0

Fig. 36. Comparison of the assumed average empirical results with the OOCS-rule and the ADMCS-rule (by the author)

2.6.3. Dynamic models, low agent switching costs: relevance of the introduced OOCS-rule

In the case of low agents switching costs, the relationships are volatile. The principal may switch his supplier at any time at negligible expenses. During the period of the project, the excluded agent has enormous impact on the relationship between the cooperation partners, as he serves as the outside-option. Thus, it is the situation of permanent negotiation, or a permanent “ex ante” situation. In each round an auction is implemented (either openly or tacitly), where the excluded weaker supplier reveals his reservation bid and the actual contractual supplier expresses his maximal bid (whether true or false). This bidding refers to the residual net present values, i.e. the discounted sum of all present values from the respective round till the end of the project.

As the added value of the stronger supplier (compared with the maximal bid of the weaker supplier) is distributed equally, the appropriate allocation rule is the outside-option-modified allocation rule for coalition structures (OOCS-rule). As the OOCS-rule is a coalition-proof Nash-equilibrium,

- the agreement is stable also without the assertion by a super-ordinate institution and
- the agents do not necessarily assume each other’s rationality.

However as time-inconsistency is ubiquitous (chapter 2.3), the agreement is steadily endangered. As the OOCS-rule is in the middle of the PCore, “small changes" do not necessarily lead to the breach of agreement. As soon as the agreed profit division is not in the PCore any more, it can be blocked by the alternative subgroup, i. e. the principal would switch to the other supplier. Figure 37 depicts the profit distribution rule that assures stable agreements for low agent switching costs:

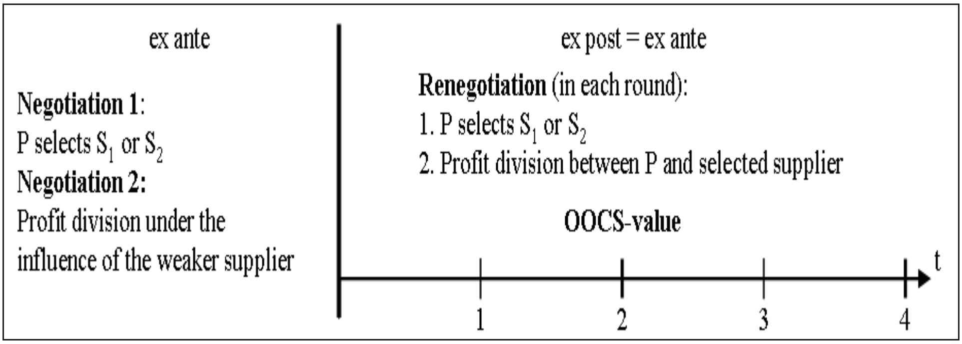


Fig. 37. supplier selection, agreement conclusion and renegotiation in project with low agent switching costs (by the author)

2.6.4. Dynamic models, high agent switching costs: relevance of the Aumann-Drèze-rule and Myerson-rule for coalition structures

If the costs of switching the agent are high, it is assumed that it is "too expensive" for the principal to switch the supplier after contract conclusion, so that the partner selection cannot be reversed, i. e. there is no outside option. However in opposite to the static models, the existing agreement between the principal and the selected supplier can be renegotiated concerning the profit division.

For example, an enterprise orders a special machine that is considered to be supervised by the supplier over a longer time. The enterprise cannot order another supplier for the supervision of this machine, but has the possibility to make the supervision on his own. The supplier can be only revised under very high expenses. However the enterprise may renegotiate the conditions with the selected supplier. Switching costs can be increased artificially by the agreement, i.e. by contractual punishment.

In the case of high agent switching costs, it has to be distinguished between

- ex ante (before the contract conclusion, negotiation) and
- ex post (after the contract conclusion, project).

Strict interpretation

The ADMCS-rule and not the OOCS-rule is the appropriate allocation rule to predict the result of the negotiation. The non-validness of the OOCS-rule in the strict interpretation becomes obvious considering the principle of backward-induction. The following procedure is implemented:

- The principal holds an auction, where the suppliers "improve" their offer iteratively
- The weaker supplier reveals his reservation bid and leaves the auction
- The principal indents to make the agreement with the strongest supplier
- Both agents predict that in the ex post phase the selected supplier would become dissatisfied with an agreement based on the OOCS-rule. He would claim the half of the total outcome in accordance with the ADMCS-rule, as soon as the weaker supplier is excluded. Therefore, the principal and the selected supplier directly make an agreement in accordance with the ADMCS-rule.

However this might seem paradox, as the weaker supplier S2 is able to exceed the offer of the stronger supplier based on the ADMCS-rule. Subsequently, S1 would exceed S2's offer. The result would be a recursive procedure that would not end in an agreement. Therefore the ex ante phase is divided into

- the auction part where both supplier participate and
- the bilateral negotiation phase, where the principal and the selected supplier negotiate about the profit division.

"Pragmatic" interpretation

The strict result is unlikely to occur in real interaction. It would be claimed that the principal and the selected supplier immediately challenge the agreement after its conclusion and start to renegotiate. It is assumed that the agreement holds 1 round before it is challenged. Thus, renegotiation starts referring the 2nd round (by the author).

Figure 38 depicts the profit distribution rules that assure stable agreements for high agent switching costs. It is distinguished between the "strict" and the "pragmatic" interpretation:

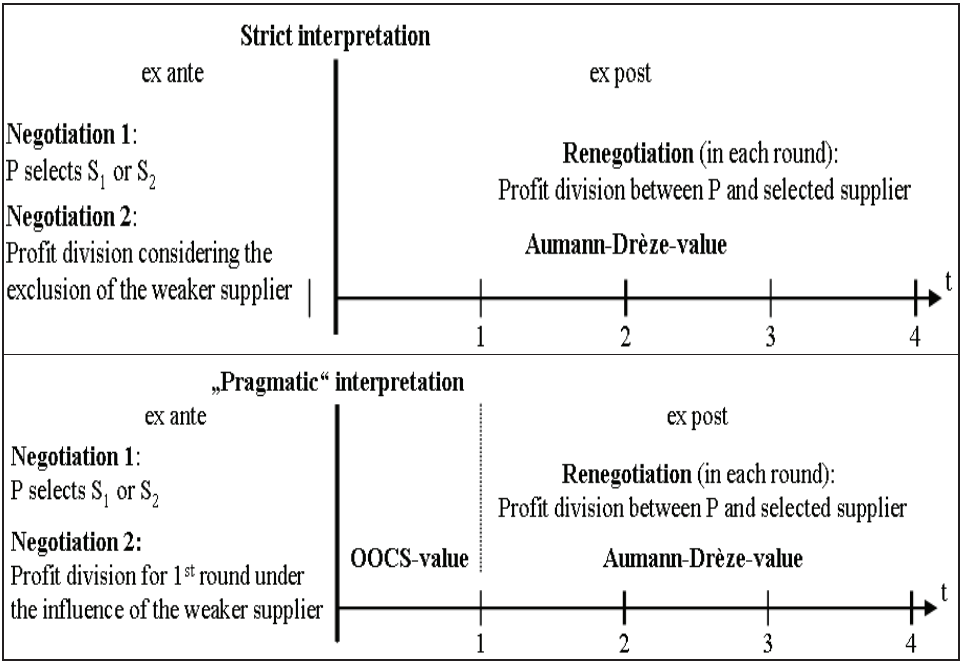


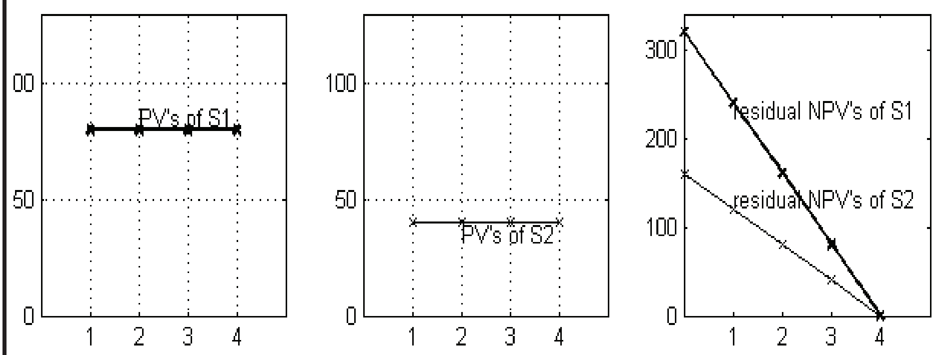
Fig. 38. Supplier selection, agreement conclusion and renegotiation in project with high agent switching costs, strict interpretation (top) and "pragmatic" interpretation (bottom) (by the author)

In order to prevent the supplier switch, a contractual punishment can be determined in the agreement. In the case of a breach of agreement, the principal would pay a penalty to the actual supplier so that the breach loses its advantageousness. The minimal contractual punishment CP is the maximal difference of the residual net present values (by the author):

$$\min(CP) = \arg\max\left(NPV_{1;\tau} - NPV_{1;\tau}\right) \qquad (3.15)$$

2.6.5. Dynamic models, special case: the residual NPV slope only with expected events

If renegotiation is possible in a round based game, the net present values have to be recalculated and updated in each round. Without unexpected events the agents move along one "residual NPV slope". Each predictable or expected event or development is already included in the NPV and does not change it. The residual NPV of agent 1 at the moment τ is expressed: $NPV_{1;\tau}$.



Supplier	Present values in period			
	1	2	3	4
S1	80	80	80	80
S2	40	40	40	40
Low agent switching costs: OOCS-rule				
P	60	60	60	60
S1	20	20	20	20
S2	0	0	0	0
High agent switching costs (strict interpretation)**: ADMCS-rule**				
P	40	40	40	40
S1	40	40	40	40
S2	0	-	-	-
High agent switching costs ("pragmatic" interpretation)**:** **1st round: OOCS-rule, 2nd – 4th round: ADMCS-rule**				
P	60	40	40	40
S1	20	40	40	40
S2	0	-	-	-
Deviations ε possible with $\varepsilon_P = \varepsilon_{S1} + \varepsilon_{S2}$ as long as allocation CPNE				

Fig. 39. Extreme case of linear residual NPV slopes of both suppliers, S1 is the stronger supplier (by the author)

Figure 39 shows the theoretical extreme case (by the author) that the principal does not have any information about events that will take place during the time of the project and are relevant for the change of the present values. In this case the residual NPV slopes are linear, i. e. the present values are constant. The left image depicts constant present values of supplier 1, the middle image of supplier 2. The right image shows their residual NPV slopes. In this case they do not cross. In the table below, the profit distributions are listed for all 4 rounds and for low and high agent switching costs in accordance with the chapters 2.6.3

and 2.6.4. For the high switching costs it is distinguished between the strict and the "pragmatic" interpretation.

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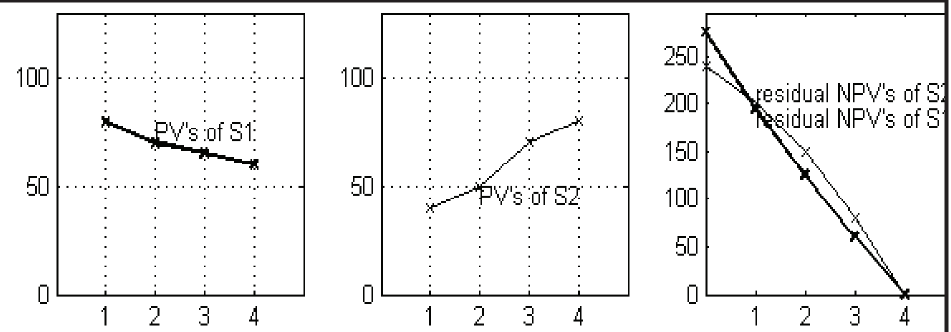


Supplier	Present values in period			
	1	2	3	4
S1	60	50	40	30
S2	40	45	55	65
Low agent switching costs: OOCS-rule				
P	50	47.5	47.5	47.5
S1	10	2.5	0	0
S2	0	0	7.5	17.5
High agent switching costs (strict interpretation)**: ADMCS-rule**				
P	30	25	20	15
S1	30	25	20	15
S2	0	-	-	-
High agent switching costs ("pragmatic" interpretation): **1st round: OOCS-rule, 2nd – 4th round: ADMCS-rule**				
P	50	25	20	15
S1	10	25	20	15
S2	0	-	-	-
Deviations ε possible with $\varepsilon_P = \varepsilon_{S1} + \varepsilon_{S2}$ as long as allocation CPNE				

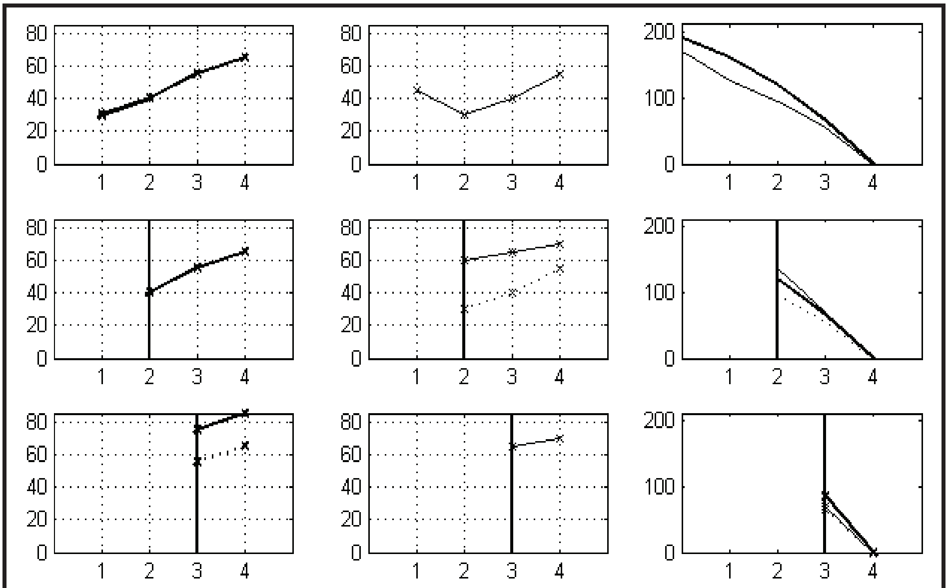
Fig. 40. Model only with expected events: present values of both suppliers, expected residual NPV changes, crossing of the residual NPV slopes (by the author)

If there is ex ante information about future changes, it is considered in the residual NPV curve (by the author). For instance, the stronger supplier may "reveal" ex ante that after the 3rd round he is able to increase his production. Or the weaker supplier that can be expected to become the outside option "reveals" that in the 4th round he makes an investment and is able to supply cheaper. It is crucial, whether the residual NPV slopes cross or not. If they do not cross, the principal does not get the wish to change his supplier. However he wants to change the profit division. Figure 40 shows the case of expected changes of the present values with the crossing of the residual NPV slopes. In the table below, the profit distributions are listed for low and high agent switching costs.

2.6.6. Dynamic models, generalization: The residual NPV slope also with unexpected events

It is more general to assume that unexpected events are possible (by the author). Due to the ubiquity of time-inconsistency, the exclusion of unexpected events is a simplification or a theoretical extreme case. As the unexpected changes of the residual NPV's take place continuously, it is important to restrict the model on "important changes". As soon as the unexpected event takes place, the agents switch to another residual NPV slope as the basis of decision.

Figure 41 shows the surprising changes for both suppliers. There are 2 "shocks" that cause changes of the residual NPV's. The upper row depicts the situation at the outset. The upper-left image shows the present values for each round of supplier 1, the upper-middle image those of supplier 1. The upper-right image shows the residual NPV's of both suppliers. The principal should select supplier 1. The impact of the 1st shock is shown in middle row. It will take place in the 2nd round, without that any agent knows it at the outset. The change concerns supplier 2, who surprisingly can improve his upcoming present values. If the principal has the possibility he should switch from the 2nd to the 1st supplier. The bottom row depicts the impact of the 2nd shock, which surprisingly influences suppliers 1's upcoming present values in the 3rd round. If the principal has the possibility he should switch back from the 1st to the 2nd supplier. However the crossing of the residual NPV's does not lead to any switch of the cooperation partner in the case that the switching costs are be too high. As well, the profit distributions are listed.



Supplier		**Present values in period**			
		1	2	3	4
S1		30	40	55	65
	(Shock 1)	-	40	55	65
	Shock 2	-	-	**75**	**85**
S2		45	30	40	55
	Shock 1	-	**60**	**65**	**70**
	(Shock 2)	-	-	65	70
Low agent switching costs: OOCS-rule					
P		37.5	50	70	77.5
S1		0	0	5	7.5
S2		7.5	10	0	0
High agent switching costs (strict interpretation)**: ADMCS-rule**					
P		22.5	30	32.5	35
S1		0	-	-	-
S2		22.5	30	32.5	35
High agent switching costs ("pragmatic" interpretation)**:** **1st round: OOCS-rule, 2nd – 4th round: ADMCS-rule**					
P		37.5	30	32.5	35
S1		0	-	-	-
S2		7.5	30	32.5	35
Deviations ε possible with $\varepsilon_P = \varepsilon_{S1} + \varepsilon_{S2}$ as long as allocation CPNE					

Fig. 41. Model with 2 shocks: present values of both suppliers (left and middle column), residual NPV's (right column), shock 1 (middle row), shock 2 (lower row)

2.7. Chapter summary

- The theoretical propositions are mainly contributions by the author.
- Co-opetition is a perspective on business relationships that focuses on the concurrency of competition and cooperation (from literature). The crucial determinants of a co-opetition model are institutions, industrial boundaries and time (by the author).
- Agreements are ubiquitously time-inconsistent among others due to changing preferences, skills and information (by the author). However the dissatisfaction of some of the participating agents does not lead to a breach of contract, as long as these agents do not find advantageous alternatives.
- The author introduces the "Outside-option modified profit distribution rules for coalition structures (OOCS)", which has the axioms "Pareto-efficiency within the productive component" and "modified symmetry" (which is the result of an auction) where the principal gains by the actual partner "the maximal proposal of the excluded agent plus the half of the actual partners additional proposal".
- In co-opetition models with mass markets there are opposing incentives for acting cooperatively and non-cooperatively (collected from various literature, assembled by the author). The incentives for cooperation are the wish of achieving Pareto-efficient outcome, the threat of retaliation and cultural aspects. The incentives for defection from cooperation are the anticipation of the others' non-cooperative behavior, end game effects. Hence, no exact predictions are possible.
- In co-opetition models with individual customers it is distinguished between (by the author): high costs and low costs of switching the cooperation partner. If the switching costs are high the Aumann-Drèze-rule is appropriate. If the switching costs are low, the OOCS-rule is appropriate. If parts of the information are private, the choice of the profit distribution rule is not affected. Switching costs can be artificially generated by "contractual punishment".

3

Experimental verification of the developed theory concerning the modelling of enterprise co-opetition

In this chapter, the co-opetition models concerning the stability of agreements are practically investigated by the author by internet based experiments. The industrial supply chain models with mass markets (chapter 2.5) and with individual customers (chapter 2.6) are investigated. Ideal-typical examples have been calculated with the software "MATLAB". Internet experiments have been implemented. The economic experimental software "z-tree" has been used in order to create an environment that corresponds to the requirements of the microeconomic and game theoretic models. The results of the experiments are evaluated and compared with the theoretical predictions.

3.1. The implementation of the experiments

3.1.1. Overview of the deployed software

The programs that are deployed for the experiments are:

- Microsoft Word,
- MATLAB (matrix laboratory),
- z-tree (Zurich Toolbox for Readymade Economic Experiments),
- Microsoft Excel,
- Microsoft Powerpoint.

Microsoft Word

Microsoft Word is the most widespread document preparation system. The dissertation has been written using the program.

MATLAB

MATLAB is a mathematical program that has been originally developed for numerical calculations which remains its emphasis. Additionally, in newer versions the possibility of symbolical calculations has been introduced. It is a popular program in the industry and in the academic world. The term "MATLAB" stands for "matrix laboratory". MATLAB's strengths are matrix manipulations, the plotting of functions and data and the implementation of algorithms that are written in a proper programming language.

In the thesis it is used in the experiments with mass markets for:

- the calculation of quantities, prices and profits at the Cournot-equilibrium,
- different graphical depictions of the collected empirical data,
- the comparisons and evaluations of the collected empirical data in order to prove or disprove the theoretical predictions.

It is used in the experiments with individual customers for:

- the graphical depictions of the predictions of the profits of the different rounds in the case of expected and unexpected events (it has been used in chapters 2.6.5 and 2.6.6 for the introductory examples in the figures 39, 40 and 41),
- the analysis of the collected empirical data and its depiction in comprehensive tables,
- the comparisons and evaluations of the collected empirical data in order to prove or disprove the theoretical predictions.

z-tree

The games of the experiments have been programmed on the software platform "z-tree" that has its core competence at round-based computer experiments for the research in game theory and microeconomics. It can be implemented in PC-pools and via the internet. In the z-tree tutorial (Fischbacher 2007), the program is described as follows:

- "z-Tree (Zurich Toolbox for Readymade Economic Experiments) is a software for experimental economics. The z-Tree program was developed at the University of Zurich. This software package allows to develop and to carry out economic experiments. In this program features that are needed in most experiments are generally defined. Among them are the communication between the computers, data saving, time display, profit calculation and tools for screen layout. A further strength of the program lies in the versatility: It can be used for a wide range of possible experiments such as public good experiments, structured bargaining experiments or markets - including double auctions and Dutch auctions. Moreover, experiments can easily be composed and combined."
- "z-tree" has its own programming environment which demands of the programmer to use various graphical elements that are hierarchically structured. Additionally it has a proper programming language that is object-oriented. Before the program is executed, the graphical programming elements and the included source code are transformed by the program into a source code text.

The network communication is based on the internet protocols TCP/IP, i. e. "z-tree experiments can be implemented both in a PC-Pool and over arbitrary distances. The program is executed in a network on a "z-tree server". Clients of arbitrary number can log into the server. The program that has to be installed on the client computers is called "z-leaf". If the clients are not in the same local area network (LAN) like the server, they have to find the server over the public internet. Then, each participant that plays on distance has to be instructed to do the following preparation steps:

- Making a directory with a copy of "z-leaf.exe",
- Copying the file "server.eec", which contains the IP-number (e. g. 192.168.2.102) of the server into this same directory,
- Adapting the firewall settings on the client computer.

In the thesis it has been used to program all experimental games. Each round consists of:

- a stage with decision (and in some games negotiation) masks,
- a stage for the profit depictions.

Microsoft Excel

Microsoft Excel is the most widespread spreadsheet application. It is also a powerful tool for data analysis. It is used to store the experimentally recorded data. Furthermore the data is categorized. It is used in order to recognize, group and count the participants' decisions or certain combinations of decisions. These are the preparation steps for the graphical depictions that are made with MATLAB.

Microsoft Powerpoint

Microsoft Excel is the most widespread application for presentations and the production of figures. The vast majority of the figures or components have been made with Powerpoint.

3.1.2. Description of the particular experiments

In accordance with the chapters 2.5 and 2.6,

- the mass market games with backward-induction based decisions and
- the games with individual customers, where outcomes are predicted with the allocation rules like the ADMCS-rule and the OOCS-rule

are investigated (Stein, Ginevičius 2010b) by the author and voluntary participants.

Mass market games are bilateral, due to the fact that the experiment participants can be only in the role of the individual agents. The mass market itself just reacts on decisions and these decisions are anticipated by the participants. Based on table 14 in chapter 2.5 the following questions are investigated:

- The stability of agreements facing the opposite incentives for non-cooperative and cooperative decisions,
- The impact of the possibility of negotiation on the actual decisions, if agreements are non-binding,
- The impact of retaliation in TIT-FOR-TAT models,
- End game effects: the break-down of cooperation at the end of round-based games.

As shown in figure 42, it is distinguished whether:

- The suppliers are not linked,
- The suppliers are linked.

Furthermore it is distinguished between:

- Games with unique decisions, i. e. static games,

– Dynamic games with round based decisions.

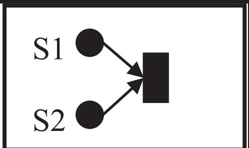
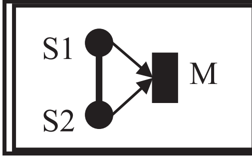
Suppliers	Network	Rounds	Chapter		z-tree file
	Not linked	1	3.2.2.	1	3.2.211-cournot-equilibrium. ztt, Appendix C
		5		3	
	Linked	1	3.2.2.	2	3.2.2.2-cournot-negotiations. ztt, Appendix C
		5		4	

Fig. 42. 4 experiments with mass market games

All other networks with mass markets from figure 28 are based on the "trivial components" of figure 29. Therefore they are not delved here.

For the games with individual customers it is investigated, whether the stability of agreements can be achieved by the allocation rules in the way, as it is proposed in chapter 2.6. The practical investigation is made in order to confirm or reject the predictions of whether human deciders behave according to:

– the ADMCS-rule,
– the introduced OOCS-rule.

The cases are shown in which the OOCS-rule is superior in comparison with the ADMCS-rule. The dynamic games are divided into those with

– high costs of switching the cooperation partner and those with
– low costs.

Furthermore the games are distinguished referring the "information problems", i. e. between

– the special case of purely public information and the general case of possible private information and
– the special case of purely expected events and the general case of possibly unexpected events.

If the agent switching costs are high, presumably the weaker supplier is excluded and the game is played bilaterally. The case with unexpected events is not regarded, due to the fact that in a bilateral game there is no significant difference to the case of only expected events. In both cases both remaining agents simply renegotiate their profit division. Hence, the 6 relevant experiments with individual customers are depicted in figure 43.

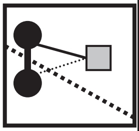
Network	Rounds	Agent switching costs	Information		Chapter	
			Events	Of other agents		
	4	High	Only expected	Complete	3.3.1.	1
				Incomplete		2
	4	Low	Only expected	Complete		3
				Incomplete		4
	4	Low	Also unexpected	Complete	3.3.2.	1
				Incomplete		2

Fig. 43. 6 relevant experiments with individual customers

Several variants of games with individual customers are excluded:

- The 3 networks of figure 30, as they consist of "trivial components",
- Static auction games (1-round), being implicit in the last rounds of the games with low agent switching costs,
- The grand coalition and the restricted grand coalition from figure 31, being not relevant for the OOCS-rule and the ADMCS-rule because of not having agents that are excluded.

3.1.3. The implementation of the experiments over the internet

The experiments have been implemented via the internet. The participants have been collected via social networks like the worldwide successful "www.facebook.com" and the German language "www.meinvz.de". Acquaintances have received announcements which they have sent to their acquaintances. Personal email contact has been built up with about 60 people, which have received a small electronic package with the client program "z-leaf.exe" and the file "server.eec", which contains the IP-address of the server. All participants had to adapt the firewall settings, in order to enable the connection of the client to the server. Over the time, when the participants have been collected, the z-tree server program has been running and the participants had to log into the server for testing, which has been recorded.

For each experiment implementation a particular appointment has been made with a fixed time. The number of implemented experiments has depended on the actual participants. All participants received emails with instructions. After about 10 minutes, the experiments have started with test rounds. This procedure has been repeated, until all planned experimental games have been implemented.

10 experimental games have been played 48 times per each, i.e. 480 games have been played (Stein, Ginevičius 2010b). 8 separate teams of 6 participants have been established. The number of participants has to be divisible through 2 and 3, i. e. through 6, in order to enable the division of the participants into groups of 2 or 3 agents. Each group has played each one of the 10 games 6 times.

The participants do not know more in advance about the investigation than that it is connected with game theory or micro-economics. In the instructions the rules and aims of the game are shown. The participants have to pass one or more practicing rounds in order to understand the game profoundly. The profound game understanding is an important precondition for micro-economic research, in order to give the possibility for the participants to make decisions close to rationality, in accordance with the ideal of the "homo economicus". The program surface is a structured collection of forms and the decisions are made in a round-based way. Decisions are made by selecting a "radio button" (typical multiple-choice selector) or typing amounts of money into the according fields. There is a time limit, which allows on the one side profound contemplation, and on the other side puts pressure on the participants to make a decision. If the participant decides to let the time expire, it is equal to the decision of withdrawal. The freedom of possible withdrawal is essential in all games, despite of the fact that the withdrawal itself is not rational.

The entries of the participants are automatically collected by z-tree in a spreadsheet that can be opened by "MS Excel". All relevant "z-tree" data, i.e. about the decisions and profits has been selected and copied manually into "MS Excel" files for the evaluation. The collected data of the 10 games has been graphically depicted, interpreted and used for the comparison with the theoretical predictions. The results of the mass market game experiments are shown in cake and bar charts. The results of the games with individual customers are shown in tables.

3.1.4. Peculiarities in the work with the participants

During the preparation phase of the experiments a variety of experience has been collected that has had much influence on the parameter setting of the games. The crucial challenge is the bounded rationality (chapter 1.2) of the participants. Six referring important issues are listed in table 15:

Table 15. Peculiarities in the work with the participants

1.	Participants make mistakes using the program.
2.	Decision problems should not be too complex.
3.	Decision problems should not be too simple.
4.	The aims of the game can be easily misunderstood and have to be explained profoundly.
5.	Auction games without private information: the parameters should be selected in a way that all participants have the incentive to participate in the bidding.
6.	The organization of the games in the internet is challenging.

1. The participants do mistakes using the programs. In auction games they frequently select the weaker supplier or a bad offer accidentally. Therefore the programs should be explained profoundly. Profound understanding is a prerequisite for rational decisions.
2. Games have to be constructed in a sufficiently simple way, in order to avoid comprehensive introductions into economic theory and to avoid the phenomenon that participants make decisions under time pressure that are not profoundly understood.
3. Monotony is an important cause for participants' exhaustion. Subsequently, games should not be too simple and should be perceived as a kind of entertainment. If a game has the same decision procedure in each round, there should not be too many rounds. The games should be played in an order that the more entertaining games are at the beginning.
4. There are frequently misunderstandings about the aims of the games. Participants often think that they just fight against each other, assuming wrongly it would be a zero-sum game. Subsequently, the participants have to be told again and again, that their aim is the maximization of their own profit, and others' higher profits do not necessarily harm oneself. For instance, this is remarked at the user interface.
5. In auction games without private information the problem occurs that the weaker participant does not see any reason in participating in the bidding procedure. This is not considered by the theory and biases the results. As reaction, the maximal bids should be close to each other in order to give the weaker participant the perception that he can win. Furthermore, the bids should have small numbers in order to facilitate tough negotiations about very small differences in the bids. Therefore no maximal bid exceeds "100".

6. The explanation of the games via internet is more complicated than with personal dialogue in a PC-pool. Instructions have been sent to all participants and particular questions have been answered via email.

3.2. Investigation of the cases with 2 suppliers and a mass market

3.2.1. Ideal-typical example of decision matrix for the mass market models

The 4 experiment games with mass markets that are depicted in figure 43 have always the same decision matrix in order to be comparable. The matrix has to symbolize the conflict between individual rationality, which leads to the Cournot-Nash-equilibrium, and the collective rationality, i.e. Pareto-efficiency, which enables the cartel solution. In the chapter 2.4.1.4 the calculation formulas for Cournot-Nash-equilibria and for cartel solutions in oligopolies are comprehensively explicated. The peculiarity of the mass market games is that there are both incentives to decide in accordance with the Cournot-Nash-equilibrium (individual rationality) and with the cartel solution (collective rationality, Pareto-efficiency).

- The variable cost parameters are chosen symmetrically and
- The level of homogeneity of the product or service is high,

in order to maximize the incentive to play cooperatively. With asymmetric variable costs one supplier would obtain an inappropriately large advantage, i. e. the added value or the incentive to play cooperatively becomes small or negative. With strongly heterogeneous goods the suppliers' decisions would not affect each other sufficiently. Table 16 shows the results of the calculations of chapter 1.4.1.4, i. e. the quantities, the market price, the profits and the added value with the parameters:

$$a = 20\,;\ d = 0.9\,;\ c_1 = 1;\ \ c_2 = 1 \tag{4.1}$$

The added value of achieving the cartel solution in comparison with the Cournot-Nash-equilibrium is 10.66 % in this case.

Table 16. Quantities, market price, profits and added value of both suppliers in the Cournot-Nash-equilibrium and the cartel solution

Symmetric cost functions		
	Duopoly	Cartel
Quantity supplier 1	6.5517	5.00
Quantity supplier 2	6.5517	5.00
Total quantity	13.10	10
Price	7.55	10
Profit supplier 1	42.93	47.50
Profit supplier 2	42.93	47.50
Total Profit	**85.85**	**95.00**
Added value	**9.15**	
	10.66%	

In table 17 the profits for both suppliers are depicted that result from the combinations of the suppliers' decisions. Instead of the reaction functions from chapter 2.4.1.4, each supplier may decide "quasi-continuously" between the quantities "5", "5.5", "6" and "6.6". The cartel solution is (5; 5) and the Cournot-Nash-Equilibrium is (6.5517; 6.5517).

Table 17. Profits for different combinations of quantities of both suppliers with possible individual quantity decisions "5", "5.5", "6" and "6.5517"

	5		**5.5**		**6**		**6.5517**	
	S1	S2	S1	S2	S1	S2	S1	S2
5	**47.5**	**47.5**	45.2	49.5	43	51	40.5174	52.0749
5.5	49.5	45.2	47.025	47.025	44.55	48.3	41.8191	49.1266
6	51	43	48.3	44.55	45.6	45.6	42.6208	46.1783
6.5517	52.0749	40.5174	49.1266	41.8191	46.1783	42.6208	**42.9252**	**42.9252**

In order to make rational decisions easier for human deciders, the matrix should be transformed into more handy numbers, without changing the structure of the decision problem. Therefore the numbers are rounded in table 18 (left). In the fields that depict the profits of (6; 6) and (6.6; 6.6), the rounding is made in a way that contradicts the usual conventions. However, the structure of the decision problem remains identical and the numbers are more clearly represented. On the right side of table 18 fixed costs of $F = 40$ are introduced. Fixed costs are strategically irrelevant in this case. However the relative distance between the best and the worst decisions is strongly reduced in order make the decision problem more clearly arranged for human deciders. The lower-left triangle that includes the diagonal comprises all possible combinations of the participants' decisions.

Table 18. Rounded profits of table 17 (left), consideration of fixed costs of 40 (right)

	Rounded values from table 17							
	5		**5.5**		**6**		**6.6**	
	S1	S2	S1	S2	S1	S2	S1	S2
5	**48**	**48**	45	50	43	51	41	52
5.5	50	45	47	47	44	48	42	49
6	51	43	48	44	45	45	43	46
6.6	52	41	49	42	46	43	**44**	**44**

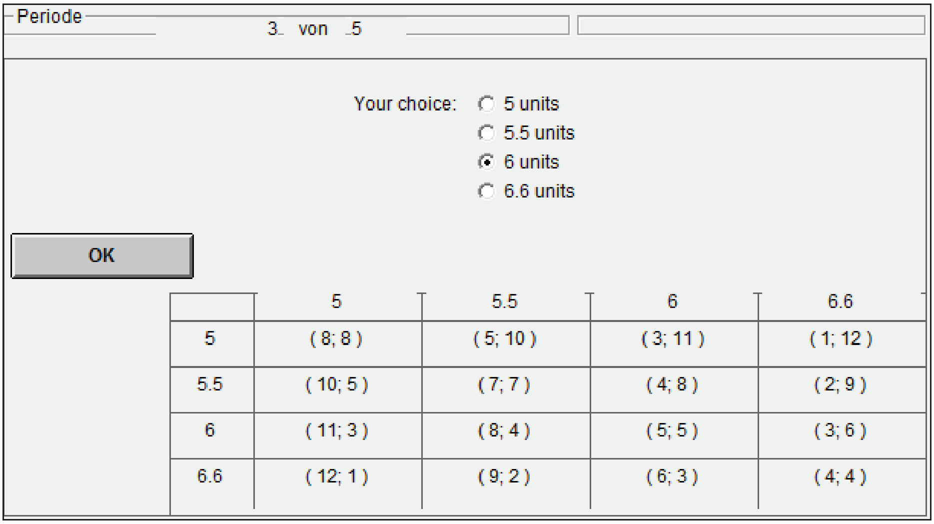
	Inclusion of fixed costs of 40							
	5		**5.5**		**6**		**6.6**	
	S1	S2	S1	S2	S1	S2	S1	S2
5	**8**	**8**	5	10	3	11	1	12
5.5	10	5	7	7	4	8	2	9
6	11	3	8	4	5	5	3	6
6.6	12	1	9	2	6	3	**4**	**4**

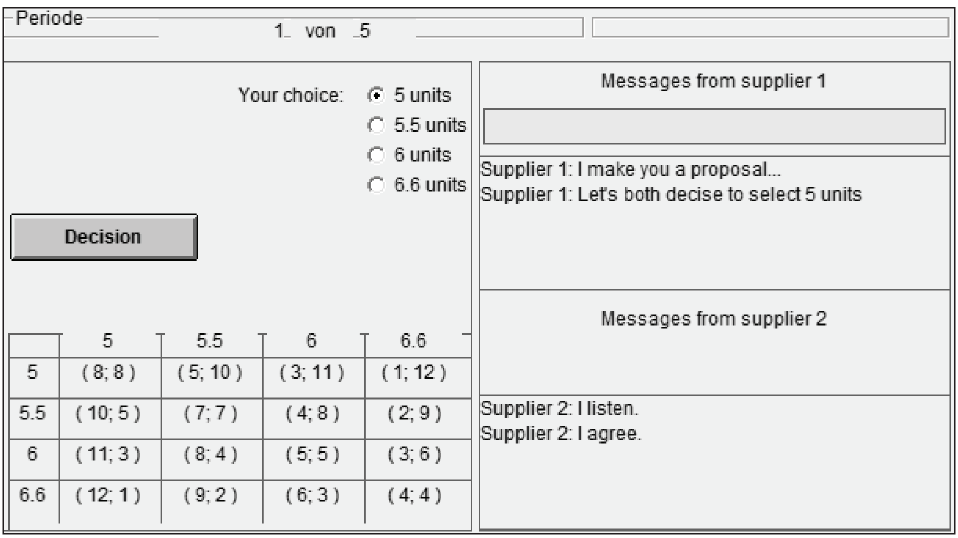
The matrix on the right side of table 18 is finally used for all mass market experiment games. The calculations of the tables 16 and 17 have been made with the MATLAB files "cournot_werte_berechnung.m" and "cournot_werte_schnell.m" (Appendix C).

3.2.2. Experiments with the software "z-tree": 2 suppliers and a mass market

The participants play against each other, sitting at the client computers and using the client program "z-leaf". All 4 mass market games have the user interface as shown in figure 44. In the upper row of figure 44 the decision masks are shown that are in accordance with table 18 (right). On the upper-left image, negotiations are not possible, which on the upper-right side they are possible through the chat boxes. In the chat boxes a conversation is shown, where both participants commit to decide cooperatively. However this commitment is not binding. Both participants are able to defect.

The lower-left image lists the own result and the results of the competing supplier. In the case of round-based games the history of previous rounds' profits is listed. The lower-right image only refers to round-based games, where the profits for both participants and the history of previous rounds' profits are shown as a bar chart:


Periode
3. von 5
Your choice:
5 units
5.5 units
6 units
6.6 units
OK
5 5.5 6 6.6
5 (8; 8) (5; 10) (3; 11) (1; 12)
5.5 (10; 5) (7; 7) (4; 8) (2; 9)
6 (11; 3) (8; 4) (5; 5) (3; 6)
6.6 (12; 1) (9; 2) (6; 3) (4; 4)


Periode
1. von 5
Your choice:
5 units
5.5 units
6 units
6.6 units
Decision
5 5.5 6 6.6
5 (8; 8) (5; 10) (3; 11) (1; 12)
5.5 (10; 5) (7; 7) (4; 8) (2; 9)
6 (11; 3) (8; 4) (5; 5) (3; 6)
6.6 (12; 1) (9; 2) (6; 3) (4; 4)
Messages from supplier 1
Supplier 1: I make you a proposal...
Supplier 1: Let's both decise to select 5 units
Messages from supplier 2
Supplier 2: I listen.
Supplier 2: I agree.

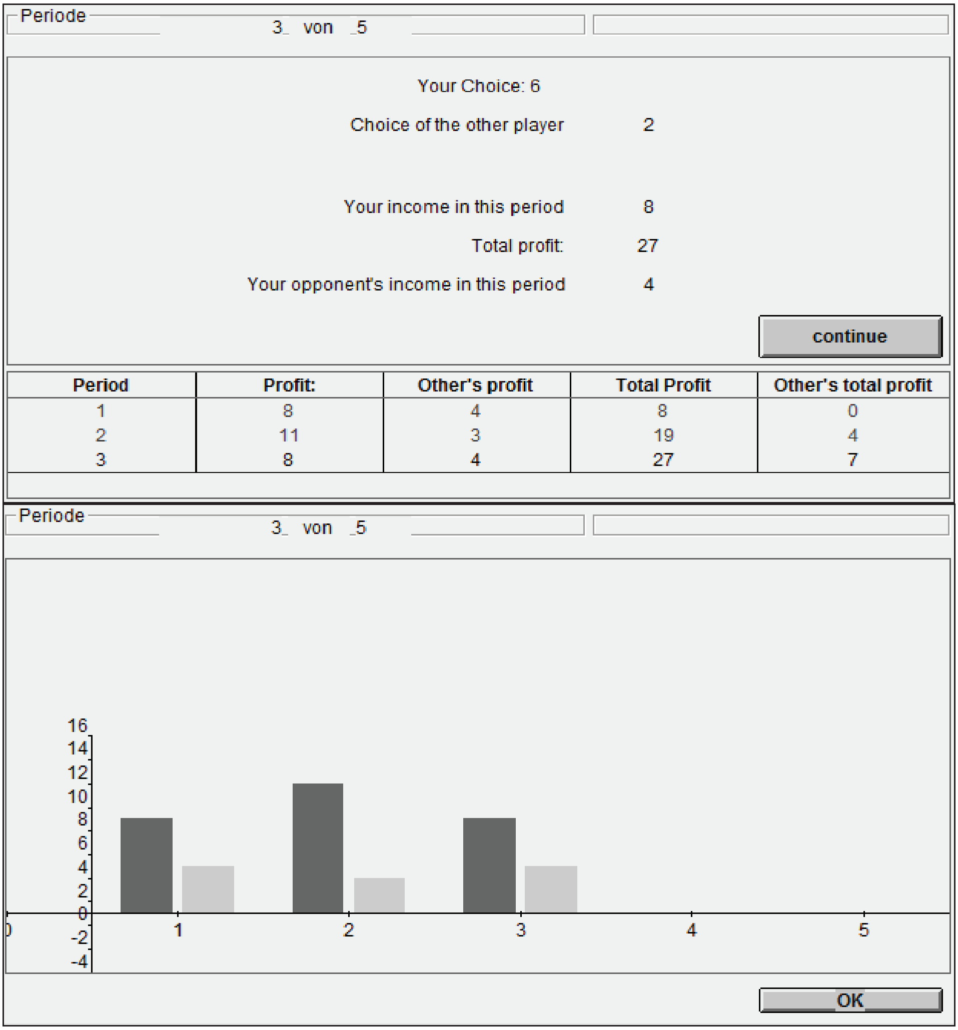


Fig. 44. Decision masks for games without (upper-left) and with (upper-right) communication, depiction of present and past profits for oneself and the other agents as table (lower-left) and bar chart (lower-right) masks

3.2.2.1. Experiment 1: Unique decisions without communication

In the 1st experiment there are 2 suppliers that:

- do not have the possibility to communicate,
- make a unique decision.

The game is repeated 48 times, using the upper-left decision mask of figure 44. Each round is one game. The rounds are not connected, and in each round the participants do not know each other. All quantity decisions of all experiments are counted. As the decision matrix is symmetric, the participants' decisions are not counted separately.

Figure 45 shows the relative and absolute frequencies of the separate decisions (left) and the combinations of the both participants' decisions (right). Due to the fact that no communication is possible it can be assumed that the participants decide "non-cooperatively" and select the quantity "6.6" (left) and just decide in accordance with the Cournot-Nash-equilibrium (right).

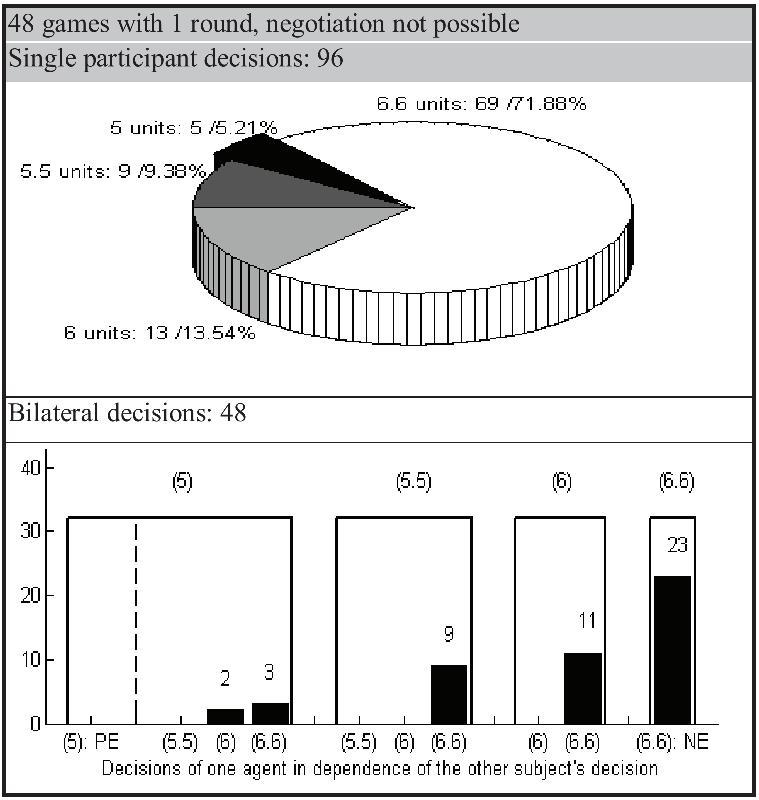


Fig. 45. Relative and absolute frequencies in static game without communication, totally 48 games with 96 individual decisions, separate decisions (left), combinations of both participants' decisions (right)

3.2.2.2. Experiment 2: unique decisions and the possibility of negotiations

The 2nd experiment is characterized by 2 suppliers that:

- have the possibility to communicate and may negotiate,
- make unique decisions.

The game is repeated 48 times, using the upper-right decision mask of figure 44. Each round is a game and after each round the participants are assigned to new pairs. The participants can use the chat boxes for negotiations, as long as they have sufficient reliance to talk with each other. They may negotiate about the quantities, however the agreement is non-binding.

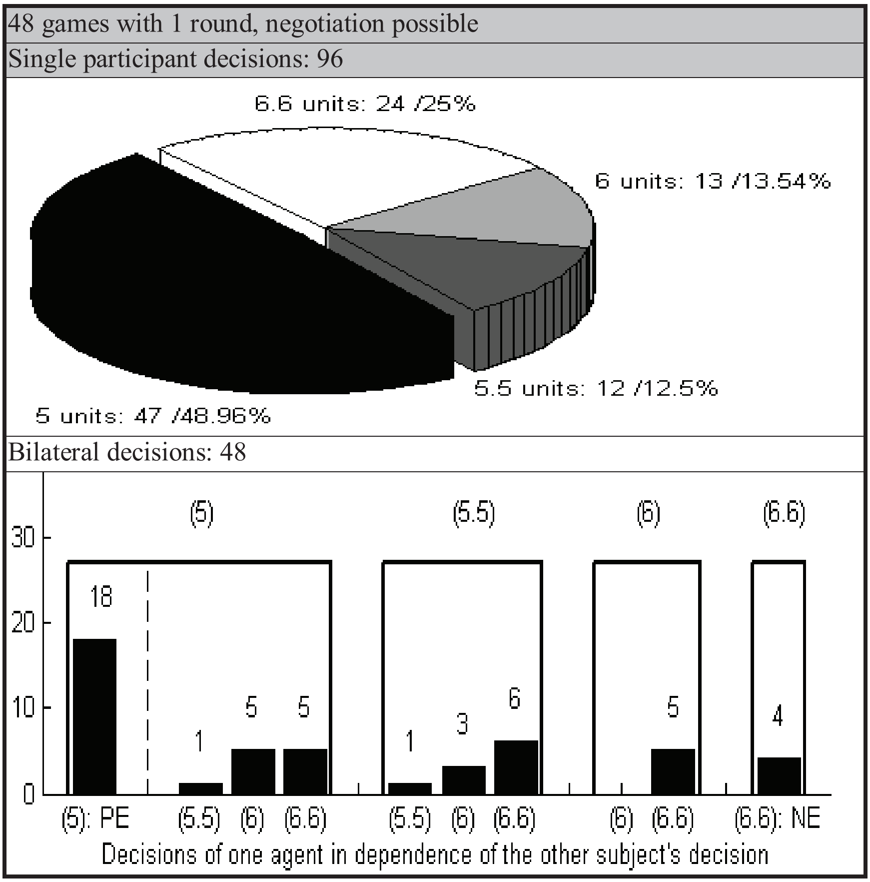


Fig. 46. relative and absolute frequencies in static game with communication, totally 48 games with 96 individual decisions, separate decisions (left), combinations of both participants' decisions (right)

As shown in chapter 2.5, the theoretical predictions are ambivalent. On the one hand, the possibility of negotiation gives to the participants the possibility to achieve the mutually advantageous cartel solution, which is decision 1 (5 units). On the other hand, the cartel solution is not stable, due to the fact that retaliation in a later round is not possible. Each agent has the incentive to defect from the cartel solution. In that case decision 4 (6.6 units) is the mutually optimal solution, though it is not Pareto-efficient. Figure 46 shows the absolute and relative quantities of the participants' unilateral and bilateral decisions in the experiment.

3.2.2.3. Experiment 3: round-based game without communication

The 3nd experiment is also implemented 48 times. There are 2 suppliers that:

- do not have the possibility to communicate,
- make a series of decisions over 5 periods.

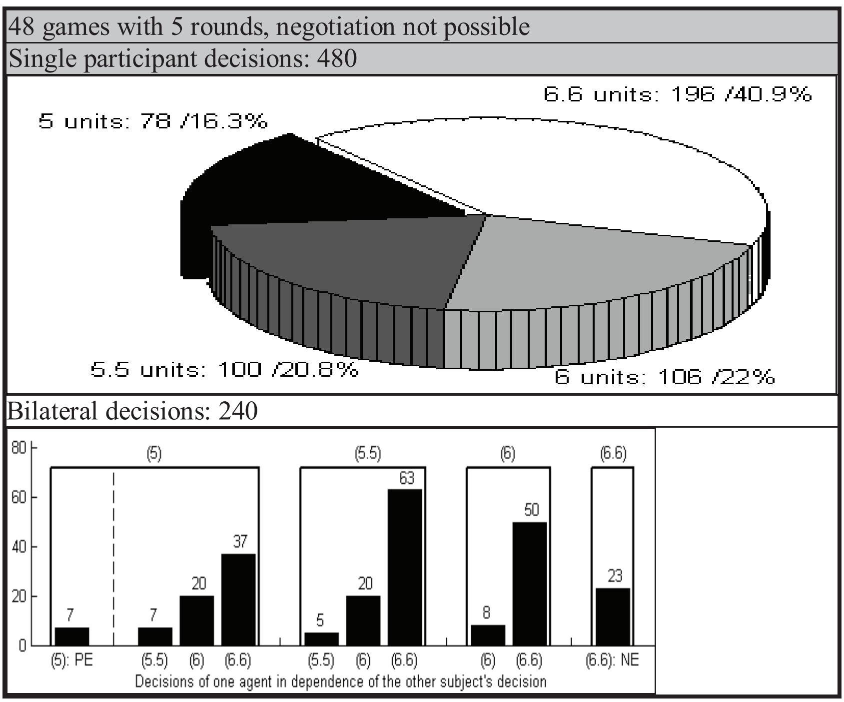


Fig. 47. Relative and absolute frequencies in 5-rounds game without communication, totally 48 games with 96 individual decisions, separate decisions (left), combinations of both participants' decisions (right)

The experiment participants are connected as pairs at the beginning and keep the same opponents till the end round. Precise theoretic predictions are not possible either. As they cannot directly communicate (or do not trust each other at all), the communication takes place through the mutual observation of the past decisions. According to the principle of TIT-FOR-TAT models the threat of retaliation of aggressive decisions represents an incentive to cooperate. Additionally to the general incentive to decide non-cooperatively, in the last round there is no more threat of retaliation. Therefore the last round is strategically equivalent to a static game. It has to be considered that the end game effects endanger cooperative behavior over the whole game (2.4.1.5). Figure 47 has the same structure like the previous 2 figures:

3.2.2.4. Experiment 4: round-based games and the possibility of negotiations

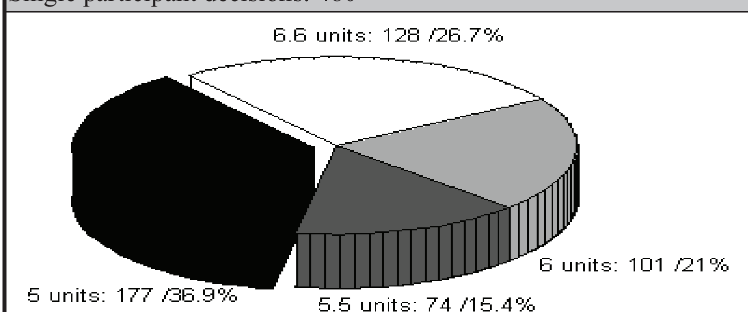
In the 4th experiment the 2 suppliers:

- have the possibility to communicate,
- make a series of decisions over 20 periods.

The participants may negotiate about the quantities and the agreements are non-binding. In addition to the previous experiment, the possibility of negotiation might be an additional incentive to cooperate, despite of the problems of the end game effects. The combination of multiple rounds and negotiations leads to the most complex "relationships" between the participants of the 4 mass market experiments. Figure 48 has the same structure like the previous 3 figures:

48 games with 5 rounds, negotiation possible

Single participant decisions: 480



Bilateral decisions: 240

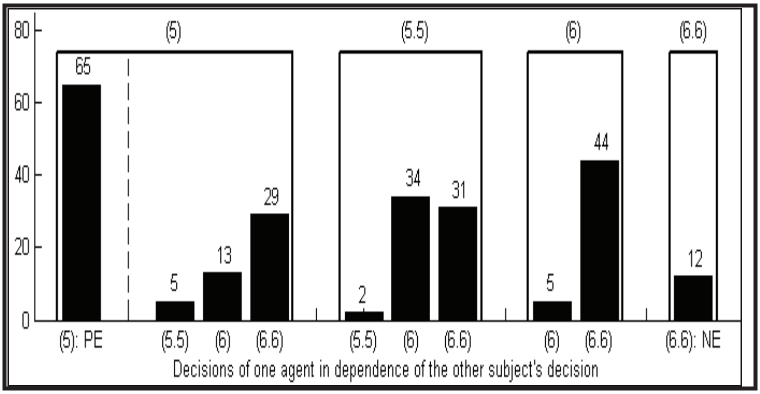


Fig. 48. Relative and absolute frequencies in 5-rounds game with communication, totally 48 games with 96 individual decisions, separate decisions (left), combinations of both participants' decisions (right)

3.3. Investigation of the cases with 2 suppliers and an individual customer

3.3.1. Ideal-typical examples for the auction models

It is an auction game, where both suppliers make the "selling bid" and the principal makes the "buying bid". If they match each other, the agreement is just concluded for the next round. The agreement is not protected by a superior institution, and time-inconsistency possibly gives incentives for renegotiation. There is the following 2-step initial (ex ante) bargaining:

- Determination of the cooperation partner and the exclusion of the weaker supplier,
- Bargaining with the selected supplier about the profit division.

In the special case that all upcoming events are known, each agent knows in advance at least his own maximal bids in of each round. All information about the future rounds is either public or private information. The principal selects the supplier that guarantees the higher residual NPV. The distinctions are between:

- Low and high agent switching costs and between,
- Whether the maximal bids of the suppliers are public or private information.

Each game is played with the participants 48 times. The results of all games are collected in a "Microsoft Excel" file. The difficulties of the participants to play rationally have been delved in the chapters 2.2 and 3.1.4. As the profit distribution rules refer to the ideal of the rational decider, participants' decisions that are obviously not rational should be sorted out. The typical example is when the principal accidentally selects the weaker supplier. A "rationality filter" is used, where all games are sorted out in which at least one "obvious mistake" has been made concerning the selection of the cooperation partner. On the other hand, all other games are counted, independent of the actual negotiation result. Afterwards average results are compared with the predictions by the OOCS-rule and the ADMCS-rule. Therefore the relative deviations, the "deviation ratios" are calculated.

Table 19. Ideal-typical examples for sequences of present values proposed by suppliers, in the case that all events are expected, distinction between low and high agent switching costs and between public and private information about the suppliers' maximal bids

Variant	**Supplier**	**Present values in period**				**Remark**
		1	2	3	4	
Low switching costs, public information	S1	50	55	70	85	Independent selection of supplier in each period (permanent "ex ante")
	S2	45	45	70	95	
Low switching costs, private information	S1	60	50	40	30	
	S2	40	45	55	65	
High switching costs, public information	S1	80	(70)	(60)	(50)	Irrevocable exclusion of "weaker" supplier in period 1 (ex ante), however selection possible by mistake periods 2-4 are "ex post"
	S2	90	75	60	45	
High switching costs, private information	S1	80	60	50	55	
	S2	70	(0)	(70)	(70)	

Table 19 shows ideal-typical developments of the four cases in 4-round-games. In the case of low agent switching costs, the principal reselects the supplier in each round (permanent "ex ante"). Therefore these are 3-agents' games in each round. If the agent switching costs are high, only the first round is a 3-agents' game, in accordance with the "case of pragmatic interpretation" in the lower image of figure 38. From the 2nd to the 4th round these are 2-agents' games between the principal and the selected supplier.

Afterwards, the general case is regarded that unexpected events may occur during the time of the cooperation relationship. These unexpected events cause the time-inconsistency of agreements and have been discussed in chapter 3.3. In figure 32 the variety of reasons for time-inconsistency is depicted. However due to the fact that the agents may enforce renegotiations in each round, there is no structural difference in the decision problem. The same z-tree games are used, but with different residual net present value functions. In games with "high agent switching costs" the problem of unexpected events is trivial. Bilateral relationships are established, where time-inconsistency can only lead to a new distribution of the updated common profit between the fixed cooperation partners. The excluded agent is no "outside option". Therefore games with "high agent switching costs" are omitted in the context of unexpected events.

The sequences of present values that the participants are confronted with are the result of the shocks that influence the residual net present values. In the "z-tree" games these shocks are already anticipated and implicit. Table 20 shows the MATLAB code that the maximal bids in the z-tree games are generated from. "out_y1" is the sequence of present values, i.e. of maximal bids that can be proposed by supplier 1. "outy1_u1" and "outy1_u2" are the updated sequences of present values. The zeros refer to rounds that already have passed. The time of the shocks is determined by the variables "shock1" and "shock2". The cases for the 2nd supplier and the game with private information are in accordance.

Table 20. Ideal-typical examples of Maximal bids and public (left) and private (right) information and shocks for both suppliers

	Maximal bids	
	Public information	Private information
Shocks	`shock1=2; shock2=3;`	`shock1=2; shock2=3;`

Supplier 1	`out_y1=  [40 45 55 65];`
	`outy1_u1=[ 0 45 55 65];`
	`outy1_u2=[ 0  0 70 80];%shock 2`
		`out_y1=  [65 55 50 40];`
		`outy1_u1=[ 0 45 40 35];%shock 1`
		`outy1_u2=[ 0  0 40 35];`

Supplier 2	`out_y2=  [50 45 50 55];`
	`outy2_u1=[0  60 65 70];%shock 1`
	`outy2_u2=[0   0 65 70];`
		`out_y2=  [55 45 35 30];`
		`outy2_u1=[0  45 35 30];`
		`outy2_u2=[0   0 45 50];%shock 2`

The sequences of maximal bids in table 21 anticipate also the private information and the expected events. Therefore the table is made, as if all information would be known. As the case of high agent switching costs is not regarded, each round is an "ex ante" situation.

Table 21. Sequences of present values proposed by suppliers according to table 20, based on unexpected events

Variant	**Supplier**	**Present values in period**				**Remark**
		1	2	3	4	
Low, complete	S1	40	45	70	80	Independent selection of supplier in each period (permanent "ex ante")
	S2	50	60	65	70	
Low, incomplete	S1	65	45	40	35	
	S2	55	45	45	50	

3.3.2. Simulations with MATLAB: Depiction of slopes, shocks and residual net present values

3.3.2.1. Only expected events, low agent switching costs, maximal bids are public information

The case of low agent switching costs and public information about the suppliers' maximal bids is shown. The left and the middle image in figure 49 show slopes of the present values of both suppliers that are close to each other. The numbers are chosen with the intention to give an incentive to the weaker supplier to participate in the bidding. Practical experience in the preparation phase of the experiments has shown that the weaker supplier does not participate in the bidding, if he sees that the difference to the stronger bidder is too big. For both suppliers the present values rise, for instance due to the acquirement of skills or particular information about the environment. However, all these changes have been expected.

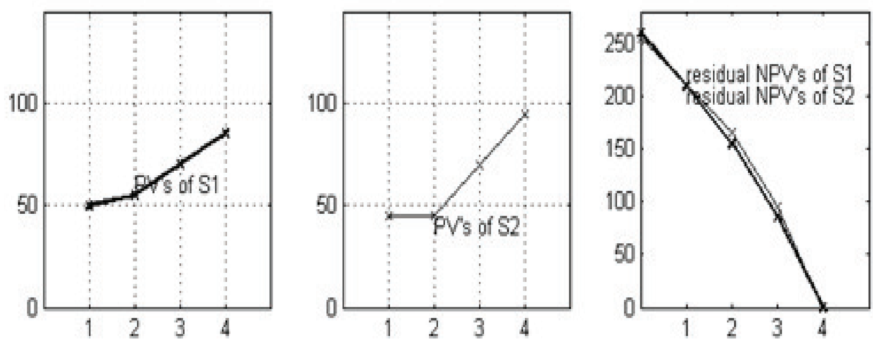


Fig. 49. Ideal-typical example of low agent switching costs and public information about the suppliers' maximal bids, present values of both suppliers (left, middle) and comparison of residual net present values (right)

In the right image it can be seen that in the beginning the principal should select the 1st supplier and switch to the 2nd one, if the suppliers and the principal act rationally.

3.3.2.2. Only expected events, low agent switching costs, maximal bids are private information

In the case of low agent switching costs and private information about the suppliers' maximal bids, which is shown in figure 50, the differences between the maximal bids of both suppliers can be bigger. The suppliers do not know the "strength" of the respective other one. Therefore they have incentive to participate in the bidding. If the suppliers and the principal play rationally, the principal selects and reselects the second supplier in each round.

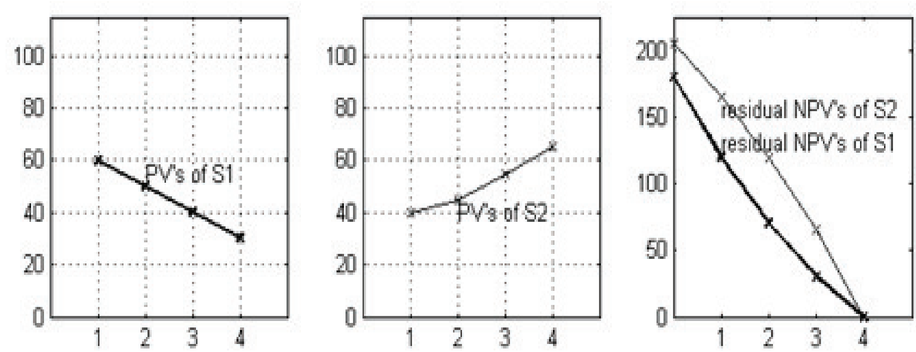


Fig. 50. Ideal-typical example of low agent switching costs and private information about the suppliers' maximal bids, present values of both suppliers (left, middle) and comparison of residual net present values (right)

3.3.2.3. Only expected events, high agent switching costs, maximal bids are public information

In this case, the principal selects irrevocably a supplier in the 1st round. The 2nd till the 4th round he renegotiated bilaterally with the selected supplier. In figure 51 the case of high agent switching costs and public information about maximal bids is depicted. If everyone acts rationally the principal selects supplier 2 in the 1st round, though the maximal bids are very close to each other, as the 1st round is played like in the case of low agent switching costs. From the second round it is a 2-agents' game with the selected supplier from round 1. If the principal selects the weaker supplier by mistake, he still may play rationally afterwards despite of his initial wrong decision.

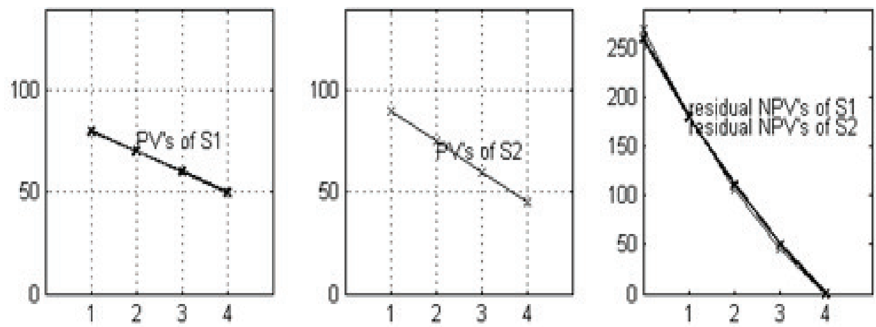


Fig. 51. Ideal-typical example of high agent switching costs and public information about the suppliers' maximal bids, present values of both suppliers (left, middle) and comparison of residual net present values (right)

3.3.2.4. Only expected events, high agent switching costs, maximal bids are private information

The last case of a round-based game where all events are expected (at least private information) is depicted in figure 52. In the 1st round it is clearly advantageous for the principal to decide for the 1st supplier, as in the 2nd round the 2nd supplier cannot offer any profit. Even if the decisions for the 3rd and 4th round would be in favor for the 2nd supplier, it is not relevant if the first round has been played rationally, due to high agent switching costs.

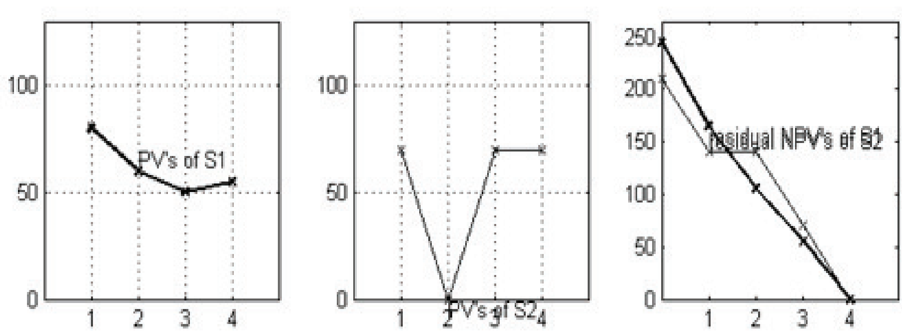


Fig. 52. Ideal-typical example of high agent switching costs and private information about the suppliers' maximal bids, present values of both suppliers (left, middle) and comparison of residual net present values (right)

3.3.2.5. Also unexpected events, low agent switching costs, maximal bids are public information

Figure 53 is the graphical depiction of the case of unexpected events, low agents switching costs and only public information about the maximal bids in the respective round. The left and the middle columns depict the present values for the suppliers in the referring rounds. The right column shows the residual NPV's. In the upper row the result of the information is shown, which is available before the 1st for all participants. The second row depicts the surprising change of the present values at supplier 2. For instance, the skills of the 2nd supplier rise in an unexpected way.

Suddenly it is clearly advantageous for the principal to cooperate till the end of the game with supplier 2. The second shock takes place in the 3rd round and is depicted in the 3rd row. Surprisingly, it becomes beneficial for the principal to switch to the 1st supplier for the remaining 2 rounds.

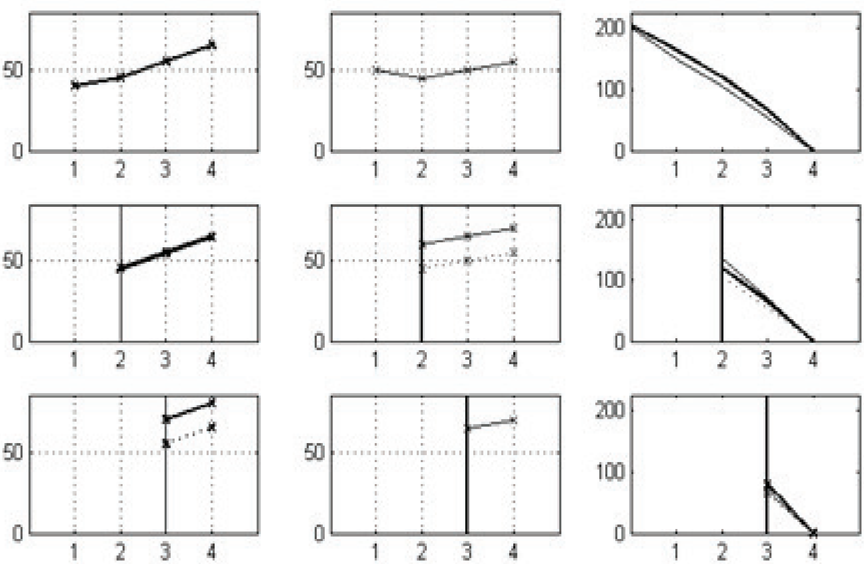


Fig. 53. Ideal-typical example of low agent switching costs and public information about the suppliers' maximal bids, present values of both suppliers (left, middle columns) and comparison of residual net present values (right column), suddenly changed situations because of 2 shocks in the 2nd and 3rd rounds (middle, lower rows)

3.3.2.6. Also unexpected events, low agent switching costs, maximal bids are private information

Figure 54 is of the same structure like the previous one, except of that the suppliers' maximal bids are private information. Initially, it is advantageous for the principal to select the 1st supplier. However, the 1st shock in the 2nd round decreases surprisingly the residual present values of supplier 1 (left column, middle row). The 2nd shock rises in the 3rd round the residual present values of supplier 2 (middle column, lower row). Suddenly it is advantageous for the principal to switch the supplier from the 1st one to the 2nd one.

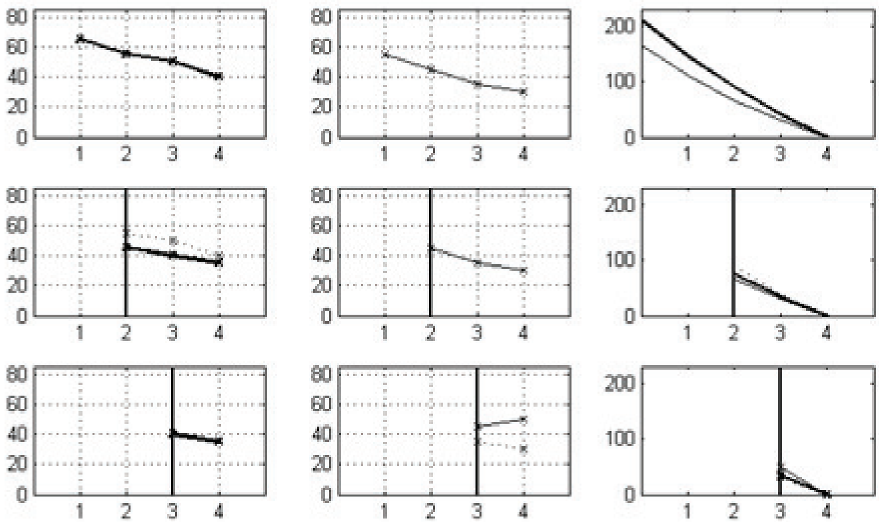


Fig. 54. Ideal-typical example of low agent switching costs and private information about the suppliers' maximal bids, present values of both suppliers (left, middle columns) and comparison of residual net present values (right column), suddenly changed situations because of 2 shocks in the 2nd and 3rd rounds (middle, lower rows)

3.3.3. Experiments with the software "z-tree": 2 suppliers and a principal

The empirical data of all experiments is listed in appendix D. In order to compare the accuracy of the profit distribution rules, the "average deviation ratios" are calculated. They are the average of the percent deviations between the respective profit distribution rule and the empirical data.

3.3.3.1. Experiment - Low agent switching costs, maximal bids are public information

Figure 55 shows the 1st stage of the game of figure 49, i.e. the auction and decision masks of the referring z-tree game (expected events, low switching costs, only public information). Each participant sees on the left side the maximal bids of the suppliers, and makes his bid. As principal it is advantageous to make a high bid. For each supplier it is advantageous to keep the bid as low as possible.

They bargain iteratively, while it is advantageous for the principal to assert an agreement with a bid that is as high as possible and for both suppliers as low as possible. Time is limited in consideration of the degree of practice of the participants. They are asked before each game whether they prefer 90, 60 or 30 seconds. If the time is over, no agreement is made and each agent gains 0. However such a result is in contradiction with the postulate of collective rationality, i. e. Pareto-efficiency.

In the 2nd and 3rd stage of this z-tree game, each participant can see his owns and the other agents' profits, in order to compare them, which is illustrated in figure 56. On the left side, the present round's profits, the total profits and the history of all previous rounds are listed. On the right side the profits are depicted in a bar chart for all 3 participants and all rounds.

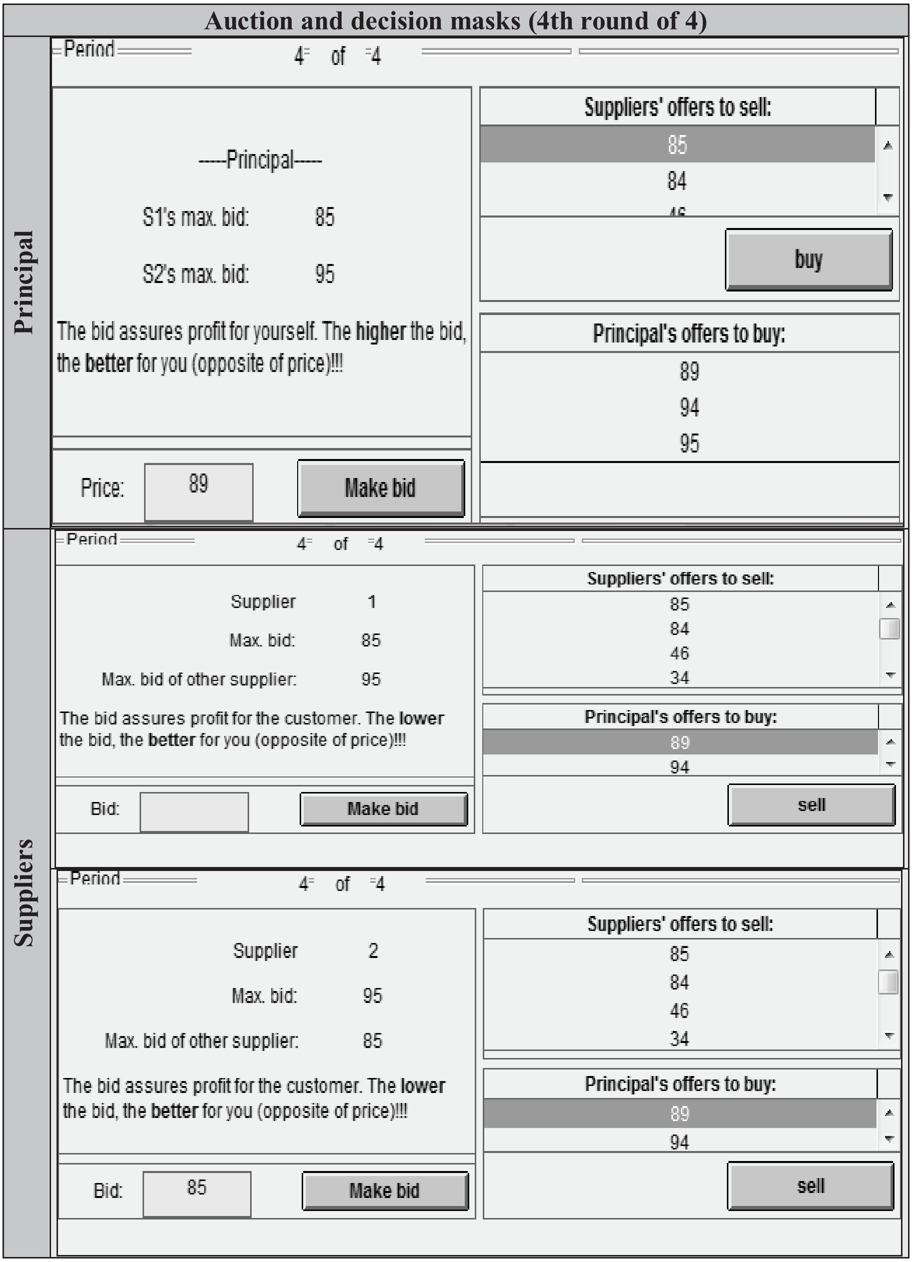


Fig. 55. 2-step initial bargaining: irrevocable determination of the supplier, profit division with him

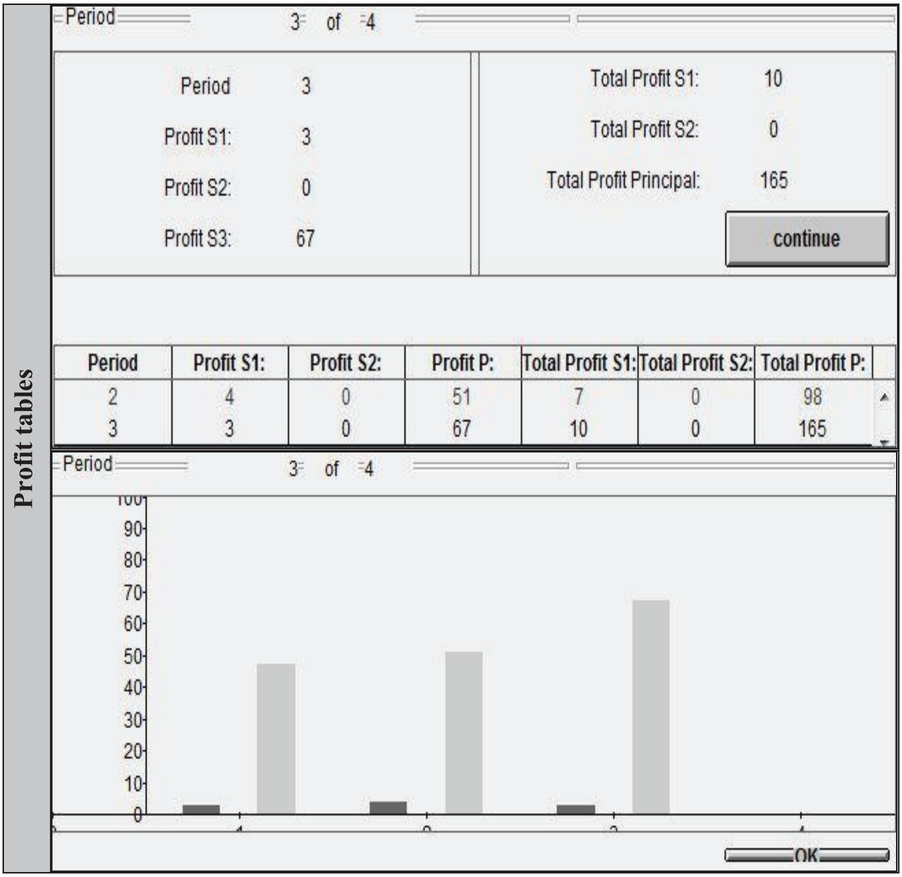


Fig. 56. Present round's profit, total profit and profit history listing (left) and bar chart depiction (right)

In table 22 the average results of the experiment of chapter 3.3.2.1 (figure 49) are compared with the predictions of the ADMCS-rule and the OOCS-rule for each round of the game. Finally, the relative deviations of the average empirical results in comparison with the ADMCS-rule and the OOCS-rule are shown.

Table 22. Maximal bids and the comparison of the OOCS-rule and the ADMCS-rule with the empirical results for low agent switching costs and maximal suppliers' bids that are public information

Case	t	Max. bid		Agent	Experiment: Average profit distributions		Prediction: Profit distribution rules		Deviation ratio	
		S_1	S_2		N=48	N=40 (rational)	OOCS	ADMCS	OOCS	ADMCS
Switching costs: Low **Events:** Expected **Max bids:** Public information	1	50	45	P	45.7	46.6	47.5	25	98%	186%
				S_1	3.4	3.5	2.5	25	138%	14%
				S_2	0.5	0	0	0	-	-
	2	55	45	P	48.2	49.1	50	27.5	98%	179%
				S_1	6.0	5.9	5	27.5	118%	21%
				S_2	0.2	0	0	0	-	-
	3	70	70	P	65.6	66.3	70	35	35 95%	189%
				S_1	2.4	2.0	0	35	0 -	12%
				S_2	1.9	1.7	0	0	35 -	10%
	4	85	95	P	86.9	89.7	90	42.5	100%	211%
				S_1	0	0	0	0	-	-
				S_2	5.7	5.3	5	42.5	106%	12%
Average deviation ratio:									**10.13%**	**88.47%**

The deviations by the OOCS-rule are by far lower, in both the unfiltered and the filtered data. The "average deviation ratio" of the OOCS-rule is: 0.1013=10.13 %. The average deviation ratio of the ADMCS-rule is: 0.8847 = 88.47 %.

3.3.3.2. Experiment-Low agent switching costs, maximal bids are private information

Figure 57 depicts the variant of the previous game where the principal does not see the maximal bids of the suppliers and the suppliers just know their own bids (chapter 3.3.2.2, figure 50). Therefore the stronger supplier is able to fool the principal about his real maximal bid. However, the principal has the possibility of imposing pressure upon this supplier by letting the time pass.

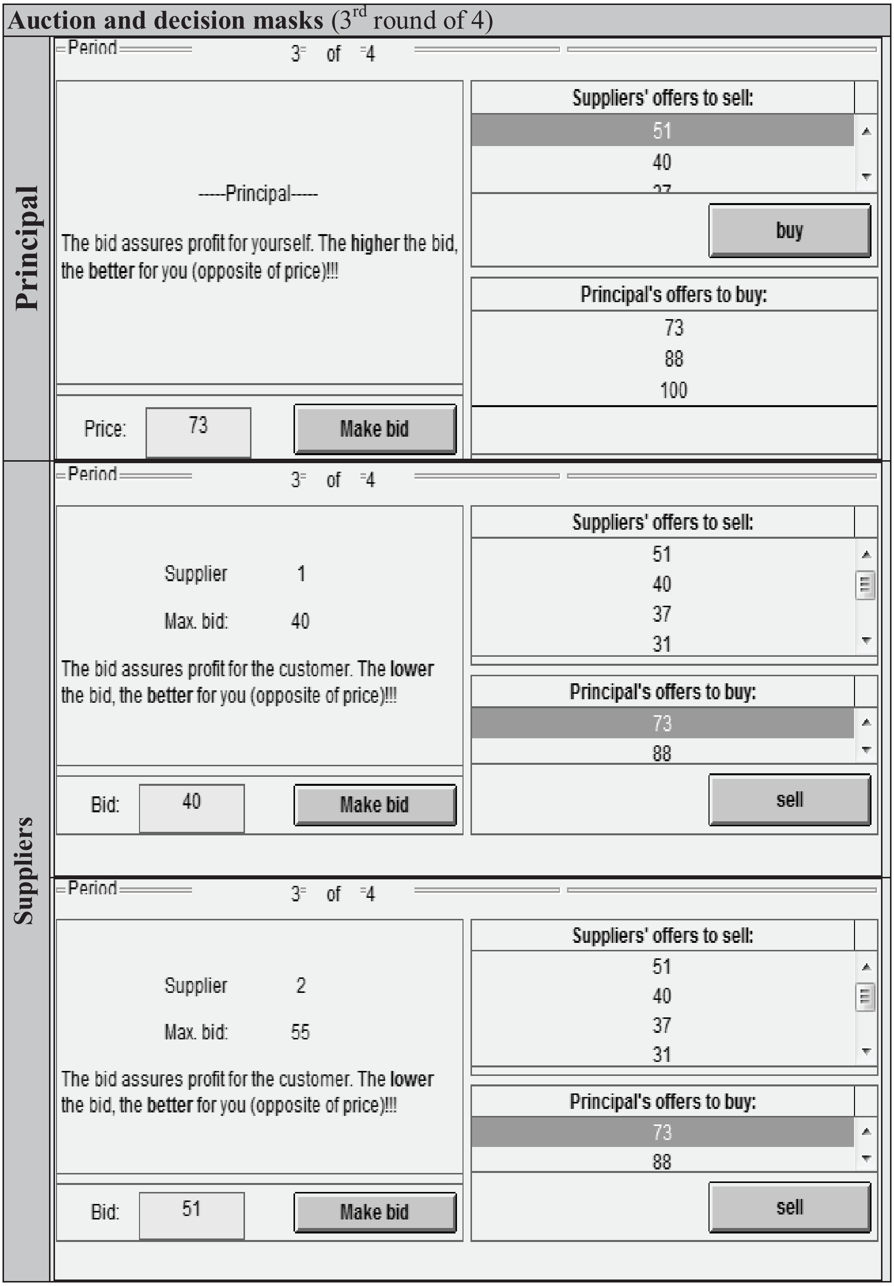


Fig. 57. 2-step initial bargaining: irrevocable determination of the supplier, profit division with him

Equally with table 22, in table 23 the accumulated and average results of the experiment are compared with the predictions of the ADMCS-rule and the OOCS-rule for each round. Afterwards the relative deviations are calculated.

Table 23. Maximal bids and the comparison of the OOCS-rule and the ADMCS-rule with the empirical results for low agent switching costs and maximal suppliers' bids that are private information

Case	t	Max. bid		Agent	Experiment: Average profit distributions		Prediction: Profit distribution rules		Deviation ratio	
		S_1	S_2		N=48	N=32 (rational)	OOCS	ADMCS	OOCS	ADMCS
Switching costs: Low **Events:** Expected **Max bids:** Private information	**1**	**60**	40	P	48.5	47.9	50	30	95%	160%
				S_1	11.1	12.1	10	30	121%	40%
				S_2	0.0	0	0	0	-	-
	2	**50**	45	P	45.3	47.0	47.5	25	99%	188%
				S_1	2.5	3.0	2.5	25	119%	12%
				S_2	0.2	0	0	0	-	-
	3	40	**55**	P	45.0	47.6	47.5	27.5	100%	173%
				S_1	0.9	0	0	0	-	-
				S_2	6.3	7.4	7.5	27.5	98%	27%
	4	30	**65**	P	45.1	45.8	47.5	32.5	96%	141%
				S_1	0.1	0	0	0	-	-
				S_2	17.0	19.2	17.5	32.5	110%	59%
Average deviation ratio:									**7.53%**	**65.46%**

The average deviation ratio of the OOCS-rule is: 0.0753=7.53 %. The average deviation ratio of the ADMCS-rule is: 0.6546 = 65.46 %.

3.3.3.3. Experiment - High agent switching costs, maximal bids are public information

The bilateral negotiations of the 2nd till the 4th round are shown in figure 58 with the example of the 3rd round. In accordance with the maximal bids of the 1st round, the 1st supplier is irrevocably excluded and "should not have" any more influence on the negotiation. The excluded participant only sees the prompt to wait, instead of the "auction and decision mask". However, the principal still can see, how much the maximal bid of the excluded supplier would have been. The supplier 2 only sees his own maximal bid.

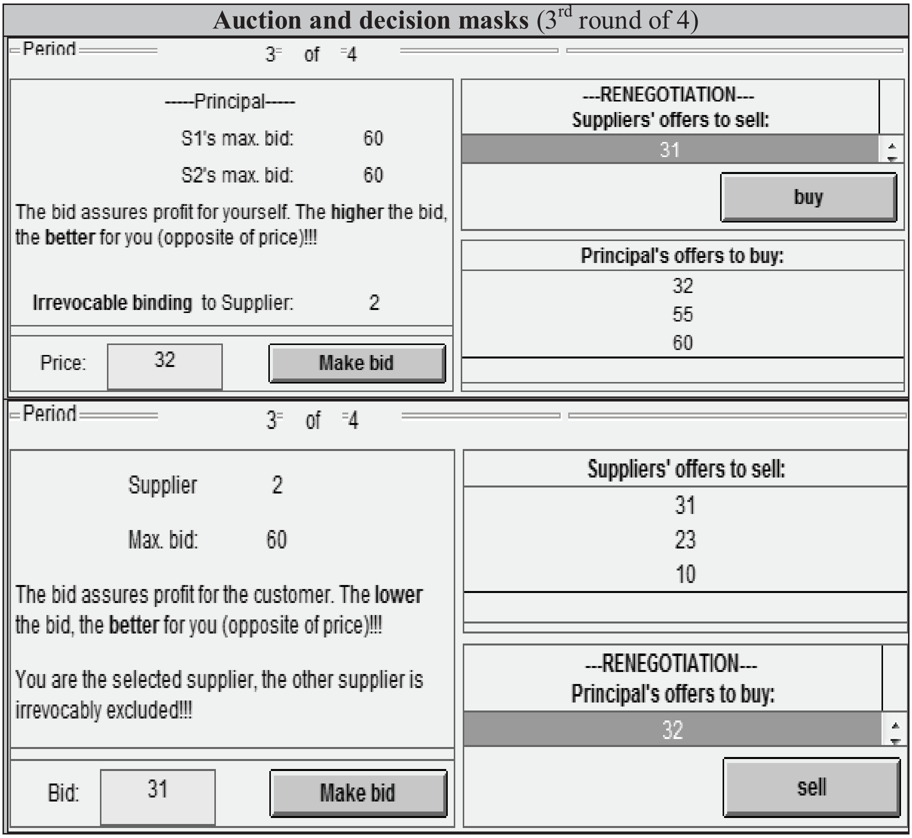


Fig. 58. 2-agents' (ex post) bargaining about profit distribution in 3rd round, after 1st supplier has been excluded irrevocably

Likewise, table 24 shows the accumulated and average results of the experiment in comparison with the predictions of the ADMCS-rule and the OOCS-rule. It refers to chapter 3.3.2.3 and figure 51. In the case of high agent switching costs, only the ADMCS-rule is relevant in the 2nd till the 4th round.

Table 24. Maximal bids and the comparison of the OOCS-rule and the ADMCS-rule with the empirical results for high agent switching costs and maximal suppliers' bids that are public information

Case	t	Max. bid		Agent	Experiment: Average profit distributions		Prediction: Profit distribution rules		Deviation ratio	
		S_1	S_2		N=48	N=34 (rational)	OOCS	ADMCS	OOCS	ADMCS
Switching costs: High **Events:** Expected **Max bids:** Public information	1	80	90	P	75.1	78.8	85	45	93%	175%
				S_1	1.5	0	0	0	-	-
				S_2	10	11.2	5	45	224%	25%
	2	(70)	75	P	39.1	43.2	-	37.5	-	117%
				S_1	2.9	0	-	0	-	-
				S_2	24.5	31.1	-	37.5	-	83%
	3	(60)	60	P	31.6	34.2	-	30 / 30	-	114%
				S_1	3.5	0	-	30 / 0	-	0
				S_2	20.0	25.8	-	0 / 30	-	172%
	4	(50)	45	P	22.9	23.5	-	22.5	-	104%
				S_1	2.2	0	-	0	-	0
				S_2	16.8	21.5	-	22.5	-	96%
Average deviation ratio:					**Round 1:**				65.71%	75.1%
					Rounds 2 – 4:				-	21.48%

In the 1st round the average deviation ratio of the OOCS-rule is 65.71 % and that of the ADMCS-rule is 75.1 %. However in the rounds 2 to 4 it is for the ADMCS-rule "just": 21.48 %

3.3.3.4. Experiment-High agent switching costs, maximal bids are private information

The bilateral negotiations of the 2nd till the 4th round are shown in figure 59 with the example of the 2nd round. The principal does not know anything about the remaining supplier and has do speculate about his actual maximal bid. However he can apply pressure through the expiring time.

Auction and decision masks (2nd round of 4)

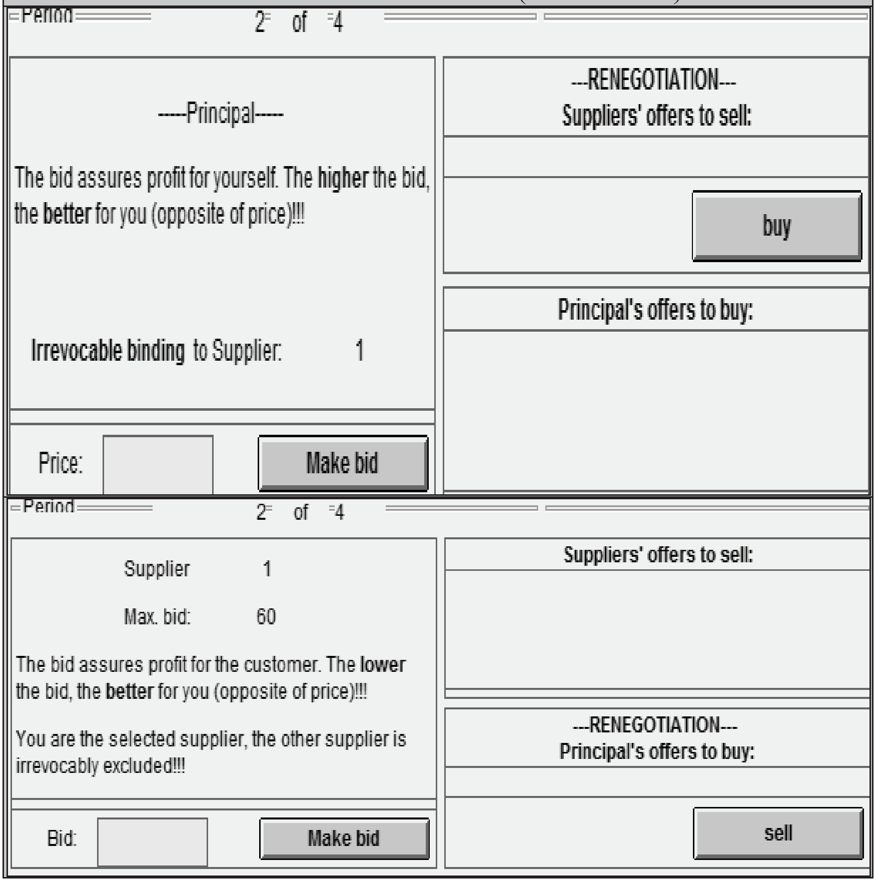


Fig. 59. 2-agents' (ex post) bargaining about profit distribution in 2nd round, after 1st supplier has been excluded irrevocably

The results in table 25 refer to the z-tree experiment game of chapter 3.3.2.4 and figure 52.

In the 1st round the average deviation ratio of the OOCS-rule is 25.17 % and that of the ADMCS-rule is 65.37 %. However in the rounds 2 to 4 it is for the ADMCS-rule "just": 11.32 %.

Table 25. Maximal bids and the comparison of the OOCS-rule and the ADMCS-rule with the empirical results for high agent switching costs and maximal suppliers' bids that are private information

Case	t	Max. bid		Agent	Experiment: Average profit distributions		Prediction: Profit distribution rules		Deviation ratio	
		S_1	S_2		N=48	N=34 (rational)	OOCS	ADMCS	OOCS	ADMCS
Switching costs: High **Events:** Expected **Max bids:** Private information	1	80	70	P	65.0	66.1	75	40	88%	165%
				S_1	11.7	13.9	10	40	139%	35%
				S_2	1.7	0	0	0	-	-
	2	60	(0)	P	26.7	33.6	-	30	-	112%
				S_1	20.8	26.4	-	30	-	88%
				S_2	0	0	-	0	-	-
	3	50	(70)	P	24.3	23.9	-	25	-	96%
				S_1	19.6	26.1	-	25	-	104%
				S_2	3.8	0	-	0	-	-
	4	55	(70)	P	33.5	32.5	-	27.5	-	118%
				S_1	17.2	22.6	-	27.5	-	82%
				S_2	4.5	0	-	0	-	-
Average deviation ratio:					**Round 1:**				25.17%	65.37%
					Rounds 2 – 4:				-	11.32%

3.3.3.5. Experiment-Also unexpected events, low agent switching costs, maximal bids are public information

The results in table 26 refer to the z-tree experiment game of chapter 3.3.2.5 and figure 53.

The average deviation ratio of the OOCS-rule is: 0.1262=12.62 %. The average deviation ratio of the ADMCS-rule is: 0.8081 = 80.81 %.

Table 26. Maximal bids and the comparison of the OOCS-rule and the ADMCS-rule with the empirical results for low agent switching costs and public information, unexpected events implicit

Case	t	Max. bid		Agent	Experiment: Average profit distributions		Prediction: Profit distribution rules		Deviation ratio	
		S_1	S_2		N=48	N=40 (rational)	OOCS	ADMCS	OOCS	ADMCS
Switching costs: Low **Events:** Unexpected **Max bids:** Public information	**1**	40	**50**	P	43.2	44.8	45	25	100%	179%
				S_1	0.3	0	0	0	-	-
				S_2	6.1	5.2	5	25	105%	21%
	2	45	**60**	P	49.0	51.2	52.5	30	98%	171%
				S_1	0.2	0	0	0	-	-
				S_2	9.3	8.8	7.5	30	117%	29%
	3	**70**	65	P	64.8	66.5	67.5	35	98%	190%
				S_1	4.9	3.5	2.5	35	141%	10%
				S_2	0.2	0	0	0	-	-
	4	**80**	70	P	71.7	73.4	75	40	98%	184%
				S_1	6.5	6.6	5	40	132%	16%
				S_2	0.8	0	0	0	-	-
Average deviation ratio:									12.62%	80.81%

3.3.3.6. Experiment-Also unexpected events, low agent switching costs, private information

Table 27 is referring to chapter 3.3.2.6 and figure 54. The empirical results and the profit distribution rules are compared:

Table 27. Maximal bids and the comparison of the OOCS-rule and the ADMCS-rule with the empirical results for low agent switching costs and also private information, unexpected events implicit

Case	t	Max. bid		Agent	Experiment: Average profit distributions		Prediction: Profit distribution rules			Deviation ratio	
		S_1	S_2		N=48	N=33 (rational)	OOCS	ADMCS		OOCS	ADMCS
Switching costs: Low	**1**	**65**	55	P	51.2	58.5	60	32.5		97%	179%
				S_1	7.5	6.5	5	32.5		130%	20%
				S_2	2.1	0	0	0		-	-
Events: Unexpected	**2**	**45**	**45**	P	39.3	40.8	45	22.5	22.5	91%	182%
				S_1	2.2	1.4	0	22.5	0	-	6%
Max bids:				S_2	2.5	2.7	0	0	22.5	-	-
Private information	**3**	40	**45**	P	37.6	41.3	42.5	22.5		97%	183%
				S_1	0.2	0	0	0		-	-
				S_2	4	3.7	2.5	22.5		149%	17%
	4	35	**50**	P	36.5	41.4	42.5	25		97%	165%
				S_1	0.3	0	0	0		-	-
				S_2	8.5	8.6	7.5	25		115%	34%
Average deviation ratio:										15.91%	79.14%

The average deviation ratio of the OOCS-rule is: 0.1591 = 15.91 %. The average deviation ratio of the ADMCS-rule is: 0.7914 = 79.14 %.

3.4. Comparison of the experiments

3.4.1. Comparison of the 4 mass market experiments with the theoretical predictions

The 4 cases of mass market experiments from chapter 3.2 are compared with the theoretic predictions of chapter 2.5.

Because of the contradictory incentives in all 4 mass market games, no clear prediction is possible about the results and the relations of the particular experiments' results. Nevertheless, the following tendencies can be listed:

1. Games with the possibility of negotiations should lead to higher profit than those without this possibility.
2. The 5-round-games should lead to higher profit than the static games

3. Especially the last rounds of the 5-round-games are equivalent to the static games and should lead to lower profit than the earlier rounds.

Table 28 gives an overview over the 4 games and the empirical panel data. Each game is described with the total numbers of decisions, the maximally and minimally possible profits and an evaluation of the empirical results. The average total profits per participant, the average profits per participant in 1 round and the average profits of a participant for each particular round are shown:

Table 28. Descriptions of the 4 mass market games with the total numbers of decision, minimal and maximal total profits and the different averages over the experimental panel data the experiment results (by the author)

Aspect		**Experiment**			
		1	**2**	**3**	**4**
Repetitions of games		48	48	48	48
Negotiations		no	yes	no	yes
Rounds per game		1	1	5	5
Total number of decisions per participant		48	48	240	240
Total number of bilateral decisions		96	96	480	480
Maximal total profits		8	8	40	40
Minimal total profits		3	3	15	15
Experimental results:					
Average total profits per participant		4.68	6.57	28.07	31.18
Average profits per participant in one particular round		4.68	6.57	5.62	6.24
Average profits for each round					
	1	4.68	6.57	5.82	6.10
	2			5.59	6.27
	3			5.61	6.64
	4			5.91	6.55
	5 (End rounds)			5.14	5.61

Additionally, in figure 60 the empirical data is graphically depicted. The average single agents' profits of the 4 cases are shown for each particular round. The average results of the static games are shown in the 1st round:

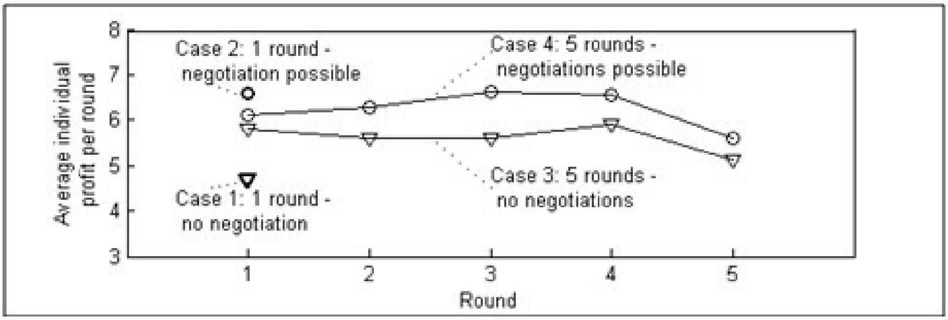


Fig. 60. Comparison of the empirical data about the individual profits in the 4 cases of mass market experiments: average single agents' profits in each round, the static games are only shown in the 1st round (by the author)

The empirical panel data is compared with the theoretically predicted tendencies:

1. Effect of negotiations:
   The comparisons of the "average total profits per participant" provide $4.48 < 6.57$ and $28.07 < 31.18$.
   Therefore, the possibility of negotiation has led to higher profits.
2. Effect of multiple rounds:
   The comparisons of the "average profits per participant in one particular round" provide $4.48 < 5.62$ but $6.57 > 6.24$.
   Hence, in the cases of no possible negotiations, the prediction has been confirmed. However in the cases of possible negotiations, the prediction has been disproved.
3. End game effects:
   The comparison of the end rounds of the 5-rounds games with the referring averages provide $5.14 < 5.62$ and $5.61 < 6.24$.
   Thus, in the implemented experiments the "end game effects" have been confirmed.

Hence, the effects of negotiation and the end game effects have been confirmed. However the effect of multiple rounds has been confirmed only in 1 of 2 comparisons.

3.4.2. Comparison of the 6 cases of individual customer experiments with the theoretical predictions

The 6 cases of individual customer experiments from chapter 2.3 are compared with the theoretic predictions from chapter 2.6. The average deviation ratios for the OOCS-rule and the ADMCS-rule are collected from the 6 experiments in chapter 3.3.3 and are listed in Table 29:

Table 29. The average deviation ratios for the OOCS-rule and ADMCS-rule, collected from the 6 experiments in chapter 3.3.3. (by the author)

Events	**Agents switching costs**	**Information**	**Recommended rule**	**OOCS-rule**	**ADMCS-rule**
Expected	Low	Only public	OOCS	10.13 %	88.47 %
Expected	Low	Also private	OOCS	7.53%	65.46%
Expected	High	Only public	ADMCS	65.71% (Round 1)	75.1% (Round 1)
				-	21.48% (Rounds 2–4)
Expected	High	Also private	ADMCS	25.17% (Round 1)	65.37% (Round 1)
				-	11.32% (Rounds 2–4)
Also unexpected	Low	Only public	OOCS	12.62%	80.81%
Also unexpected	Low	Also private	OOCS	15.91%	79.14%

Figure 61 shows for all 4 games with low agent switching costs the comparisons between the empirical data and the OOCS-rule, and between the empirical data and the ADMCS-rule.

It can be seen that in the case of low agent switching costs the introduced OOCS-rule provides a fundamentally better prediction than the ADMCS-rule and the here identical Myerson-rule for coalition structures.

In the case of high agent switching costs no direct comparison between the OOCS-rule and the ADMCS-rule is possible, as the denied supplier irrevocably leaves the game. However, in accordance with the pragmatic interpretation in figure 38 (bottom, chapter 2.6.4), the OOCS-rule refers to the 1st rounds and the ADMCS-rule with the rounds 2 to 4.

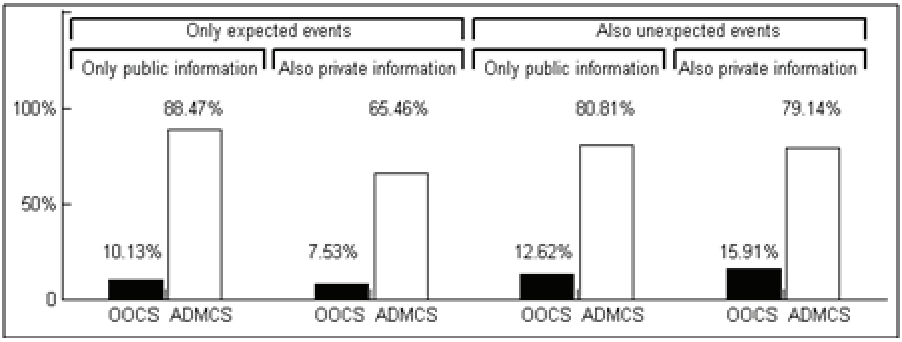


Fig. 61. Experiments with low agent switching costs, comparison between the OOCS-rule and the ADMCS-rule regarding the average deviations between the theoretic predictions and the experimental data (by the author)

In the 1st round the comparison between the OOCS-rule and the ADMCS-rule is as follows:

$65.71\% < 75.1\%$ and $25.17\% < 65.37\%$

Thus, the OOCS-rule provides a more precise prediction than the ADMCS-rule, though it is still highly inaccurate. However, as the "pragmatic interpretation" is just a trick to simplify the decision problem for human deciders, the OOCS-rule is not relevant here.

In the rounds 2–4 the ADMCS-rule is relevant. While the OOCS-rule is not calculable, the ADMCS-rule provides the average deviation ratios of: 21.48% and 11.32%. Thus, on the basis of the experimental data the ADMCS-rule has been proved to be a relatively accurate predictor for the profit distribution in the case of high agent switching costs.

3.5. Chapter summary

- The experiments with supply chains with mass markets lead to the following insights (theory has been collected from literature and assembled by the author): Negotiations influence the average profits positively (predicted by theory). Multiple round games do not necessarily have higher profits than one-rounds games (theoretical prediction not perfectly fulfilled). Cooperation is declining at the end of the cooperation period (predicted by theory).
- The experiments with supply chains with individual customers confirm the theoretical predictions that have been developed by the author: In games with high agent switching costs, the Aumann-Drèze-rule is ap-

propriate. In games with low agent switching costs the developed OOCS-rule (by the author) is appropriate.

General conclusions

1. Co-opetition – the state of the art:

There is no real theoretical foundation of co-opetition yet.

2. The proposed co-opetition framework

Co-opetition is a perspective on business relationships that focuses on the concurrency of competition and cooperation. In a co-opetition model a particular problem can be structured by the determinants:

- institutions (contracts, states, culture, trade usages, etc.),
- industrial boundaries defined by the products and/or services,
- industrial boundaries defined by the transactions of the products and/or services,
- industrial boundaries related to industrial supply chains, which are a part of the global social network and
- time (1-round vs. many round games).

3. Parts of game theory that are relevant for co-opetition – state of the art

The relations between the fields of game theory related to co-opetition are:

$$\text{Strategic games} \supset \text{network games} \supset \text{coalition games}$$

4. Industrial supply chains

The business partners in a co-opetition model are categorized into suppliers, customers, competitors and “complementors”, i. e. providers of a complementary good or service. The customers are distinguished as

- individual customers,
- mass markets.

The negotiation results can be shown exactly under the assumption that each participant behaves rationally, which is the key to analyse one’s own negotiation power. The relationships towards mass markets require backward induction.

5. Ubiquity of time-inconsistency of agreements

As the prerequisites of agreements change, at least one of the agents becomes dissatisfied with a formerly made agreement. This endangers the stability of the agreement. However as long as there is no better alternative, the agreement is not broken by a rational decider.

6. The “Outside-option modified profit distribution rule for coalition structures”

The proposed profit distribution rule refers to the case of 3 agents and consists of the following axioms:

- Pareto-efficiency within the “productive component” in the coalition structure
- “Modified symmetry”, which is similar with the “Myerson-axiom of balanced contributions”.

The OOCS-rule proposes an allocation that is stable against the deviations of subgroups of agents and is a CPNE. In opposite, the “Aumann-Drèze-rule” and the “Myerson-rule for coalition structures” that is identical in networks with 3 agents, are not stable in the sense of CPNE and ignore the outside option.

7. Stability of agreements and predictions in co-opetition models with mass markets

There are opposing incentives in order to decide cooperatively and non-cooperatively. Incentives for decide cooperatively (cartel solution) are:

- The wish to achieve (component-) Pareto-efficient outcome,
- Threat of retaliation,
- Culture or trade usages that facilitate the compliance of negotiation results.

Incentives for deciding non-cooperatively (Cournot-Nash-equilibrium) are:

- Anticiaption of the other agent's non-cooperative behavior
- Impossibility of retaliation in the last round (end game effects)

No exact prediction is possible because of contrary incentives to decide non-cooperatively and cooperatively.

8. Stability of agreements and predictions in co-opetition models with individual customers

In an auction procedure with an industrial supply chain with 2 possible suppliers, an individual customer and a coalition structure it is distinguished between

- high costs and low costs of switching the cooperation partner,
- purely public information and the possibility of private information.

In the case of low agent switching costs, the introduced OOCS-rule provides prediction about the negotiation result that enables a stable agreement under the assupmtion of rational deciders. It is superior towards the ADMCS-rule. Oppositely, in the case of high agent switching costs the Aumann-Drèze-rule provides the appropriate prediction about the profit division among the cooperating agents, due to the fact that the other agent is irrevocably excluded. If the information about the maximal bids of the agents is private, the use of the profit distribution rules is not affected. Agent switching costs can be generated artificially by the agreement on "contractual punishment.

9. Results of experimental investigation

For supply chains with mass markets the analysis of the collected experimental data leads to the following insights:

- The comparisons of the "average total profits per participant" have confirmed that negotiations influence the average profits positively.
- The comparisons of the "average profits per participant in one particular round" have partly confirmed and partly disproved the theoretical prediction that multiple round games have higher average profit than one-round games.
- The comparison of the end rounds of the 5-rounds games with the referring averages has confirmed the prediction about the decline of the average profits due to the "end game effects".

For supply chains with individual customers the following has been shown through the analysis of the collected experimental data:

- In games with low agent switching costs the OOCS-rule has been proven as accurate and significantly more precise than the ADMCS-rule,

- In games with high agent switching costs the ADMCS-rule provides accurate predictions. The OOCS-rule cannot be used in these games.

10. Possible practical value of the research

The thesis contributes to as an intermediate step in the scientific development to:

- better control over negotiations,
- the prediction of negotiation results and
- agreement stability in different settings.

In the future, enterprise software systems will offer intended rational decisions, which are relevant for business strategy. The thesis is a contribution in this direction. In this sense the thesis provides a better understanding of strategic management and business relationships in general.

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Summary in Lithuanian

Įvadas

Problemos formulavimas

Konkurencija ir kooperacija įmonių savitarpio santykiuose įgyja daug prasmių ir tampa reiškiniu, kuris tiriamas mokslininkų keliais aspektais. Vis tik nėra vieningos teorijos, pagrįstos tinkamais matematiniais skaičiavimais, kad būtų galima naudotis kompiuteriu norint apskaičiuoti ir prognozuoti įvairius tokių santykių aspektus. Būtent šiai problemai spręsti ir skirta ši disertacija. Joje nagrinėjami keli konkurencijos ir kooperacijos modeliai, kurie patvirtinami pasitelkus šiam tikslui sukurtą kompiuterinę programą.

Tiriamojo darbo aktualumas

Atliktas tiriamasis darbas rengiant disertaciją yra aktualus nagrinėjant tokius klausimus kaip:

- Koopeticijos teorijos plėtra,
- Derybų galia ir sutarčių stabilumas,
- Ilgalaikės perspektyvos siekiant patobulinti naudojamą įmonėse programą.

Koopeticija – tai neologizmas, sudarytas iš terminų konkurencija ir kooperacija. Šiuo neologizmu akcentuojamos įvairios prasmės, kurios įžvelgiamos esant konkurencijai ir kooperacijai santykiuose su visomis kitomis įmonėmis pramonės tiekimo tinkle, čia dalyvauja tiekėjai, pirkėjai (užsakovai), konkurentai ir tie, kurie aprūpina papildomomis prekėmis. Koopeticijos teorija dar tebėra pradinėje vystymosi stadijoje. Dėl sisteminių ir metodinių klaidų koopeticijos teorija taikytina tik sprendžiant įmonių savitarpio santykio problemas. Koopeticijos modeliai neturi norminio ir pripažinto apibrėžimo ar sandaros. Be to, neaišku, kokiu būdu galima naudoti šią teoriją. Todėl naujai sukurtas koopeticijos teorijos pagrindimas bei determinančių koopeticijos modeliams suformulavimas būtų svarus indėlis į šiuolaikinį mokslą. Reikėtų sutelkti dėmesį į įvairius savitarpio santykius pačiame pramonės tiekimo tinkle bei į įtaką, kurią turi nesančios tinkle įmonės, kurios visgi yra svarbios savitarpio santykiams, ypač kalbant apie derybų rezultatus ir sutarčių stabilumą.

Nuolat augant tarptautiniam verslui atskiros valstybės praranda savo svarbą, kai kalbama apie kontrakto įvykdymo patvirtinimą. Ypač tada, kai nėra pasitikėjimo valstybinėmis institucijomis, kurios gali patvirtinti įvykdymo kontraktus, labai svarbus tampa derybų galios supratimas. Derybų galia ir sutarčių stabilumas – tai svarbūs klausimai, nagrinėjami šioje teorijoje, būtent strateginės sąveikos teorijoje. Būtų daug pasiekta šioje mokslo srityje, jeigu galėtume parodyti, kokią įtaką deryboms ir sutarčių stabilumui daro tos įmonės, kurios yra už pramonės tiekimo tinklo ribų, ir kiek tiksliai galėtume prognozuoti derybų baigtis.

Per praėjusius dešimtmečius buvo stipriai išplėtota įmonių išteklių planavimo kompiuterinė programa (ERP – enterprise resource planning). Tai ženkliai palengvino bet kurios įmonės padalinio administravimą ir kontrolę. Svarbios dalys šioje sistemoje – tai inventoriaus tvarkymas ir ryšių su užsakovais valdymas. Ilgainiui pasiekta dirbtinio intelekto pažanga galėtų atverti galimybę naudoti informacinių technologijų sistemas tam, kad suprastume ir įvertintume verslo aplinką ir priimtume sprendimus, kurių tikslas kuo daugiau duoti naudos vartotojui. Šiuo atveju naujoji teorija paaiškina, kokios yra racionalaus sprendimo galimybės.

Darbo tikslai

Šios disertacijos tikslas – sukurti naują struktūrą įmonių koopeticijos modeliams, kad būtų lengviau plėtoti geriausias verslo strategijas. Gilesnis supratimas tokių klausimų kaip:

- įmonių savitarpio santykiai pramonės tiekimo tinkluose,
- įtakojantys derybų galios veiksniai ir
- sutarčių stabilumas

bus pasiektas plėtojant įvairiausias teorijas koopeticijos srityje. Sukurtoji teorija vaizduojama pasitelkus modeliavimą ir patvirtinta internetu grindžiamais eksperimentais.

Tiriamojo darbo uždaviniai

Užduotis – pateikti išsamią naujausią apžvalgą ir nustatyti tolesnio koopeticijos tyrimo rėmus, kad būtų išplėtota koopeticijos teorija, pateikiant naują bendradarbiavimo apibrėžimą, jos modelių struktūrą, o nagrinėjama teorija modeliuose naudojama kaip matematikos instrumentas, gilinantis detaliau į pateiktą koopeticijos struktūrą, sukuriant ,,pramonės tiekimo tinklą“, kur taikoma pelno paskirstymo taisyklė, kuri numato galimą įtaką iš nepriklausančių tinklui asmenų pusės dinamiškose situacijose, o tai galima panaudoti prognozuojant aukcionų rezultatą, nagrinėjant derybų rezultatų stabilumą, esant įvairiausioms sąlygoms pramonės tiekimo tinkluose, kai derybos vyksta su pirkėjais iš plačiosios rinkos ar su atskirais užsakovais, simuliuojant pelno paskirstymą per savitarpio santykius versle, naudojant idealius-tipiškus parametrus bei patvirtinant modelio padarytas prognozes dėl derybų rezultato ir sutarčių stabilumo, kai varžomasi dėl plačiosios rinkos ir atskirų užsakovų eksperimentuose su juose dalyvaujančiais asmenimis per internetą.

Naudotos kompiuterinės programos

- MATLAB: matematinė programa skaitmenims ir ženklams skaičiuoti.
- Z-tree: programa, leidžianti sukurti ir atlikti eksperimentus su naująja teorija, bei mikroekonomikos srityje.
- Microsoft Word, Excel ir PowerPoint.

Tyrimo metodai

Keli skyriai šioje disertacijoje yra skirti deduktyviam metodui (einant nuo bendros iki atskiros išvados) bei induktyviam metodui (nuo atskiros iki bendros išvados). Poskyriams yra trumpai surašyti II-jo laipsnio tyrimo metodai.

Darbo mokslinis naujumas

- Koopeticijos modelių struktūra: naujas koopeticijos ir koopeticijos modelio determinančių apibrėžimas.
- Pramonės tiekimo tinklas: toliau plėtojamas Porterio veikalas „Penkios varomosios konkurencijos jėgos pramonėje“ bei Brandenburgerio ir Nalebuffo „Value net“, „pramonės tiekimo tinklo“ integravimas į koopeticijos struktūrą.
- Išsami tiekimo grandies tinklų analizė su 2, 3 ir 4 veiksniais.
- Detalus paaiškinimas tokio reiškinio, kaip visur pasitaikantis sutarčių nesuderinamumas su laiku bei dėl to galimas jų nestabilumas.
- Tolesnis pelno paskirstymo taisyklės išplėtojimas: „objektyvios pasirinkimo galimybės modifikuota pelno paskirstymo taisyklė, taikoma koalicinėms struktūroms (OOCS = Outside option coalition structures), detalus paaiškinimas tokių atvejų, kai OOSC taisyklė yra viršesnė palyginus su Auman-Dreze taisykle ir Myersono taisykle, taikant koalicinėms struktūroms.
- Priešingo paskatinimo pramonės tiekimo tinkluose analizė, kai patariama elgtis nekooperatyviai ir kooperatyviai su plačiąja rinka.

- Derybų rezultatų (pvz., aukcionų baigties) prognozė pramonės tiekimo tinkluose ir tarp atskirų pirkėjų, taikant išvystytą (patobulintą) pelno paskirstymo taisyklę.
- Sutarčių tarp 2 įmonių stabilumo analizė, turint objektyvią pasirinkimo galimybę arba jos neturint.
- Tyrime naudotų teorinių ir makroekonominių eksperimentų drauge su programa Z-tree“ įgyvendinimas per internetą tam, kad būtų patvirtinta arba paneigta pateikta disertacijoje teorija kaip žingsnis link automatizuotų prognozės sistemų ateityje.

Praktinė vertė

Disertacija prisideda prie geresnės teorinės ir praktinės kontrolės derybų metu, padeda prognozuoti derybų rezultatus ir sutarčių stabilumą skirtingomis sąlygomis. Ateityje naudojamos įmonėse kompiuterinės sistemos priims racionalius sprendimus, kurie svarbūs verslo strategijai. Disertacija – tai indėlis šia kryptimi einant.

Šia prasme disertacija padeda apskritai geriau suprasti strateginį valdymą ir savitarpio santykius versle.

Mokslinio darbo apimtis

Disertaciją sudaro 190 puslapiai, 61 paveikslai ir 29 lentelės, pateiktas naudotos literatūros sąrašas, autoriaus publikacijų sąrašas ir priedai A–E.

Darbo struktūra

Įvadas pateikia bendrus disertacijos bruožus – tai tiriamojo darbo aktualumas, tyrimo tikslai ir uždaviniai, naudota kompiuterinė programa, metodai, novatoriškumas moksle, praktinė vertė ir apginti moksliniai darbai.

Pirmasis skyrius apima išsamią apžvalgą literatūros, susijusios su koopeticija ir giminingomis ekonomikos sritimis. Įvadas supažindina su svarbiomis strategijos, kooperacijos ir tinklo žaidimų sritimis. Galiausiai apibrėžiami tolesnio tyrimo rėmai.

Antrajame skyriuje paminėtas autoriaus indėlis į koopeticijos teoriją įvairiais aspektais, pradedant nuo naujo apibrėžimo pasiūlymo:

Koopeticija turi perspektyvą verslo savitarpio santykiuose, kadangi konkurencija ir kooperacija veikia išvien.

Žaidimo teorija yra tinkamas matematinis instrumentas formalizuotiems koopeticijos modeliams, įgalinanti prognozuoti verslo strategijų rezultatus. Koopeticijos modelyje tam tikra problema gali būti susisteminta naudojant tokias 5-ias determinantes:

- institucijos, kurios nustato verslo taisykles,
- pramonėje egzistuojantys apribojimai, kuriuos sukelia:
  - ✓produktai ir/arba paslaugos,
  - ✓sandoriai dėl produktų ir/arba paslaugų,
  - ✓pramonės tiekimo grandys, kurios sudaro dalį globalinio socialinio tinklo ir
  - ✓laikas (vieno turo žaidimas prieš daugelio turų žaidimus).

Šios 5-ios determinantės leidžia išsamiai aprašyti problemą, susijusią su verslo strategija. Verslo taisykles nustatančios institucijos pateiktos išoriškai, kai tuo tarpu apribojimams įtaką gali daryti tinklo viduje esantys veiksniai. Laiko determinantė leidžia atlikti turais grindžiamus žaidimus.

1S paveiksle pateikiamas pramonės tiekimo tinklas su savitarpio bendradarbiavimo santykiais.

Išorinės parinktys	Galimi tiekėjai (0 … n)	Galimi konkurentai (0 … n)	Galimi mažmenininkai (0 … n)	Galimi galutiniai vartotojai (0 … n)
		Įmonė: Kooperacinė valdžia Strateginis valdymas		
Išankstiniai tiekėjai	Tiekėjai (0 … n)	Papildomų prekių tiekėjai (kita rinka)	Mažmenininkai (1 … n)	Galutiniai pirkėjai Atskiri užsakovai Plačioji rinka
• Kartelis • Numanomas suokalbis		Konkurentai (0 … n)		

1S pav. ,,Pramonės tiekimo tinklas su koopeticijos savitarpio santykiais" tarp tiekėjų, konkurentų, ,,papildomų prekių tiekėjų" ir užsakovų, kurie būna atskiri asmenys arba plačioji rinka, bei tarp tokių galimų veiksnių kaip išorės parinktys

Sutartys visuomet būna nesuderinamos laike dėl besikeičiančių prioritetų, kvalifikacijos ir informacijos (autoriaus pateiktos). Tačiau kai kurių dalyvių nepasitenkinimas nepriveda prie kontrakto nutraukimo, nebent tie asmenys randa palankių alternatyvų. 2S paveiksle pateiktos tokio sutarčių nesuderinamumo laike priežastys.

	Kiti veikiantieji	Kvalifikacijos įgijimas
	Pats	
Forsmažoras		
Pokyčiai, susiję su globaliu socialiniu tinklu	**Bendra informacija apie aplinką**	Informacijos atnaujinimas
Didesnis verslo tinklas		
Savanoriška reveliacija	**Su santykiais susijęs mokymasis**	Bendras atvejis: galimi **netikėti įvykiai**, nesuderinamumas laike
Priverstinė reveliacija	Naujos žinios, kitų įgytos	
Prieš pasirašant sutartį: patikra	Pokytis kitų dalyvaujančiųjų prioritetuose	Specialus atvejis : **tikėtini įvykiai**
Po sutarties pasirašymo: stebėsena	**Pats**	

2S pav. Sutarčių nesuderinamumo laiko atžvilgiu priežastys

Autorius pristato „Išorės parinkties modifikuoto pelno paskirstymo taisykles koalicinėms struktūroms" (OOCS = outside option coalition structures), kurios turi tokias aksiomas kaip „Pareto našumas (efektyvumas) produktyviame komponente" ir ,,modifikuota simetrija" (o tai aukciono rezultatas), kur esamojo partnerio pagrindinis pasiekimas yra ,,maksimalus pasiūlymas iš atmesto dalyvio pusės plius pusė papildomo pasiūlymo iš esamų partnerių". Panašiai, kaip vyksta Shapley- taisyklės (Myerson, 1980) aksiomatizacija, kurią atliko Myersonas, OOCS taisyklė yra apibrėžta tokiomis aksiomomis.

Komponento Pareto efektyvumas: $\sum_{i \in C} OOCS(N, v, g) = v(C),$ taikomas produktyviam komponentui.

Modifikuota subalansuotų kontribucijų aksioma:

Balansuotų kontribucijų aksiomos modifikavimas susideda iš išankstinės stadijos, kur lemiantis kooperacijos partneris perduoda pralaimėjusio kooperacijos partnerio vertę pagrindiniam veikiančiam asmeniui. Po to subalansuotų kontribucijų aksioma naudojama įprastu būdu. Taigi, veikiantiesiems A, B, C є N: jeigu A turi pasirinkti kooperacijos partnerį ir v(AB) > v(AC), tuomet A pasirenka B ir pirmiausiai pareikalauja kiekio: v(AC) iš dalyvio B. Po to kontribucijos subalansuojamos:

$$OOCS_A(N, v, g) - OOCS_A(N, v, g \setminus \{B\}) = OOCS_B(N, v, g) - OOCS_B(N, v, g \setminus \{A\})$$

Taigi A ir B pasidalina skirtumą tarp B ir C pasiūlymų po lygiai. Koalicinėje struktūroje (Stein, 2010a), kai A ir B „produktyviame komponente" ir C, o išorės parinktis tenka A, tai OOCS taisyklė taikoma v(AB) > v(AC):

$$OOCS - rule = \left(\frac{v(AB) + v(AC)}{2}; \frac{v(AB) - v(AC)}{2}; 0 \right)$$

Palyginimui, ADMCS taisyklė užrašoma tokia lygtimi:

$$ADMCS - taisyklė = \left(\frac{v(AB)}{2}; \frac{v(AB)}{2}; 0 \right)$$

Koopeticijos modeliuose su plačiąja rinka pasitaiko priešingų skatinimų veikti kooperatyviai ir nekooperatyviai. Kooperacijos skatinimas reiškia norą gauti Pareto efektyvų rezultatą, atpildo grėsmę ir kultūros aspektus. Skatinimas pasitraukti iš kooperacijos rodo, kad numatomas ir kitų dalyvių nekooperatyvus elgesys, tai galutinis žaidimo efektas. Taigi, negalima daryti tikslių prognozių. 1S lentelėje pateikiama schema.

1S lentelė. Diskusija apie kooperacijos stabilumą modeliuose su plačiosios rinkos vartotojais, priklausomai nuo turų skaičiaus ir derybų galimybės

Argumentai už	**Modelis su 2 tiekėjais ir plačiąja rinka**			
	Laikas: 1 turas		**Laikas: daugiau nei vienas turas**	
	Jokių derybų	**Derybos galimos**	**Jokių derybų**	**Derybos galimos**
Stabilumas: skatinama žaisti kooperatyviai	Noras pasiekti Pareto efektyvų rezultatą			
		Derybų rezultatai gali būti paisomi dėl kultūros arba prekybos vartojimo		Derybų rezultatai gali būti paisomi dėl kultūros arba prekybos vartojimo
			Atpildo grėsmė	
Nestabilumas: skatinama žaisti nekooperatyviai	Galimybė gauti didesnį pelną kito dalyvio sąskaita			
	Jokios atpildo grėsmės			
	Jokios komunikacijos		Komunikacija tik stebint ankstesnius turus	
			"Galutinis žaidimo efektas": lygybė su vieno turi žaidimais per paskutinį raundą dėl to, kad nėra atpildo grėsmės	

Koopeticijos modeliuose su individualiais užsakovais sulyginama aukšta kaina (pagal autorių) keičiant kooperacijos partnerę ir žema kaina.

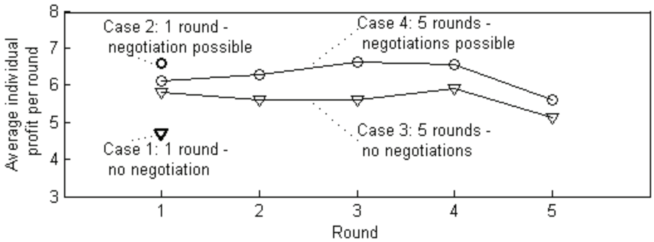
- Jeigu pakeitimo kaštai yra dideli, tai čia tinka Aumann-Dréze taisyklė
- Jeigu pakeitimo kaštai maži, tai tinkama yra pateikta OOCS taisyklė.

Jeigu informacijos dalys yra privačios, tai pelno paskirstymo taisyklės pasirinkimas nuo to nenukenčia. Pakeitimo kaštai gali būti dirbtinai sukurti pagal ,,kontraktuose numatytą bausmę".

Trečiasis skyrius pateikia eksperimentinį pasiūlytos teorijos patvirtinimą. Koopeticijos modeliai, susiję su sutarčių stabilumu, praktiškai būna tiriami internetu pagrįstuose eksperimentuose. Pramonės tiekimo tinklo modeliai su plačiąja rinka ir su atskirais vartotojais buvo išnagrinėti. Idealūs tipiški pavyzdžiai buvo apskaičiuoti su programa „MATLAB“. Interneto eksperimentai buvo įgyvendinti. Ekonominių eksperimentų kompiuterinė programa „Z-tree“ buvo naudojama norint sukurti aplinką, kuri atitinka mikroekonomikos reikalavimus ir žaidimo teorinius modelius. Eksperimentų rezultatai yra įvertinti ir palyginti su teorinėmis prognozėmis. 2 lentelė rodo skaitmeninius rezultatus ir plačiosios masės rinkos žaidimų analizę:

2S lentelė. Aprašymas 4 plačiosios rinkos žaidimų, esant bendram sprendimų skaičiui, minimaliam ir maksimaliam bendram pelnui ir skirtingiems vidurkiams iš eksperimento duomenų bazės, eksperimentų rezultatai

Aspektas		**Eksperimentas**			
		1	**2**	**3**	**4**
Žaidimų kartojimas		48	48	48	48
Derybos		no	yes	no	yes
Turai viename žaidime		1	1	5	5
Bendras sprendimų skaičius vienam dalyviui		48	48	240	240
Bendras skaičius dvipusių sprendimų		96	96	480	480
Maksimalus bendras pelnas		8	8	40	40
Minimalus bendras pelnas		3	3	15	15
Eksperimento rezultatai:					
Vidutinis bendras pelnas dalyviui		4.68	6.57	28.07	31.18
Vidutinis pelnas vienam dalyviui per vieną turą		4.68	6.57	5.62	6.24
Vidutiniai pelnai kiekvienam ture					
	1	4.68	6.57	5.82	6.10
	2			5.59	6.27
	3			5.61	6.64
	4			5.91	6.55
	5 (Galutiniai turai)			5.14	5.61



Vidutinis asmeninis pelnas viename ture
1 atvejis: 1 turas – derybos galimos
2 atvejis: 1 turas – jokių derybų
3 atvejis: 5 turai – derybos galimos
4 atvejis: 5 turai – jokių derybų

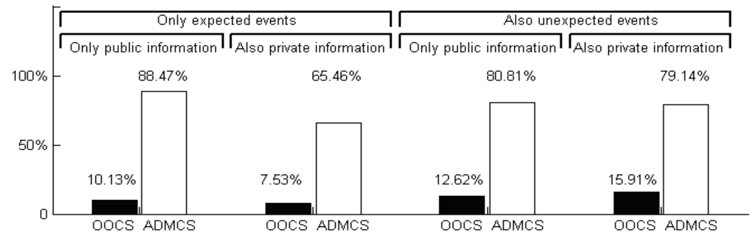
3S pav. Palyginimas empirinių duomenų apie asmeninius pelnus 4 atvejais vykdant eksperimentus plačiojoje rinkoje: atskirų veikiančiųjų pelno vidurkiai per kiekvieną turą, statiški žaidimai parodyti tik per 1 turą

3S paveiksle grafiškai sujungiami skaitmeniniai rezultatai su atitinkamais turais. 3 lentelėje pateikiami skaitmeniniai rezultatai ir žaidimų su atskirais vartotojais analizė.

3S lentelė. Vidutiniai nukrypimo santykiai taikant OOCS taisyklę bei ADMCS taisyklę, surinkti iš 6 eksperimentų skyriuje 3.3.3. (autoriaus)

Įvykiai	Dalyvių pakeitimo kaštai	Informacija	Rekomenduojama taisyklė	OOCS taisyklė	ADMCS taisyklė
Tikėtini	Maži	Tik vieša	OOCS	10.13 %	88.47 %
Tikėtini	Maži	Ir privati	OOCS	7.53%	65.46%
Tikėtini	Dideli	Tik vieša	ADMCS	65.71% (1 turas)	75.1% (1 turas)
				-	21.48% (2-4 urai)
Tikėtini	Dideli	Ir privati	ADMCS	25.17% (1 turas)	65.37% (1 turas)
				-	11.32% (2-4 turai)
Taip pat netikėti	Maži	Tik vieša	OOCS	12.62%	80.81%
Taip pat netikėti	Maži	Ir privati	OOCS	15.91%	79.14%

4S paveiksle pateikti visi 4 žaidimai, kai veikiančiųjų (dalyvių) pakeitimo kaštai buvo maži, ir palyginama su empiriniais duomenimis bei OOCS taisykle ir su empiriniais duomenimis bei ADMS taisykle.



Tik tikėtini įvykiai — Taip pat netikėti įvykiai

Tik vieša informacija Ir privati informacija — Tik vieša informacija Ir privati informacija

4S pav. Eksperimentai su mažais dalyvių pakeitimo kaštais, palyginimas OOCS taisyklės ir ADMCS taisyklės, kalbant apie vidutinius nukrypimo tarp teorinių prognozių ir eksperimento duomenų (pagal autorių)

Eksperimentai su tiekimo tinklais plačiojoje rinkoje priveda prie tokio supratimo: derybos teigiamai įtakoja vidutinius pelnus. Daugelio turų žaidimai nebūtinai duoda geresnius pelnus nei vieno turo žaidimai. Kooperacija mažėja kooperavimosi laikotarpio pabaigoje. Atlikti tiekimo tinklų su atskirais užsakovais eksperimentai patvirtina teorinę prognozę, kurią išplėtojo autorius: žaidimuose, kai dalyvių pakeitimo kaštai būna dideli, tinka taikyti Aumann-Dréze taisyklę. Žaidimuose su mažais kaštais tinkama būtų išplėtota OOCS taisyklė.

Bendros išvados

1. Koopeticija– naujausi duomenys:

   dar nėra realaus teorinio koopericijos pagrindo.

2. Siūloma koopeticijos struktūra.

Koopeticija – verslo savitarpio santykių perspektyva, kai dėmesio centre yra vienu metu veikianti konkurencija ir koopeticija. Koopeticijos modelyje tam tikra problema gali būti suformuota taikant tokias determinantes kaip institucijos, pramonės aplinka, laikas.

3. Pramonės tiekimo tinklai

Verslo partneriai koopeticjos modelyje skirstomi į tokias kategorijas kaip tiekėjai, užsakovai, konkurentai ir ,,papildomų prekių ar paslaugų tiekėjai“. Užsakovai skirstomi:

- atskirus vartotojus,
- plačiąją rinką.

Derybų rezultatus galima tiksliai parodyti, jei darysime prielaidą, kad kiekvienas dalyvis elgsis racionaliai, o tai raktas į savo galios derybose pažinimą. Santykiai su plačiąja rinka reikalauja grįžtamosios indukcijos.

4. Sutarčių nesuderinamumas laike

Kai keičiasi būtinos sutarčių sąlygos, tai bent vienas iš dalyvių tampa nepatenkintas anksčiau pasirašyta sutartimi. Tai stato į pavojų sutarties stabilumą. Vis tik, kol nebus geresnės alternatyvos, sutartis nebus nutraukta, jei dalyvis sprendžia reikalus racionaliai.

5. Siūloma ,,Išorinės parinkties modifikuoto pelno paskirstymo taisyklė koalicinėms struktūroms"

Remiasi trijų dalyvaujančių veiksnių atveju ir susideda iš tokių aksiomų: Pareto efektyvumas ,,produktyvaus komponento" ribose, kai struktūros koalicinės, ,,Modifikuota simetrija", kuri panaši į ,,Myersono subalansuotų kontribucijų aksiomą".

OOCS taisyklė siūlo tokį išdėstymą, kuris būtų stabilus ir nepasiduotų veikiančiųjų pogrupių nukrypimams. Priešingai, ,,Aumann-Dréze taisyklė" ir ,,Myersono taisyklė koalicinėms struktūroms", kuri būna identiška tinkluose, kai dalyvauja 3 pusės, nebūna stabili ir ignoruoja išorinę parinktį.

6. Sutarčių stabilumas ir prognozavimas modeliuose, dalyvaujant plačiajai rinkai.

Pasitaiko prieštaringų skatinimų spręsti reikalus kooperatyviai ir nekooperatyviai. Skatinimas spręsti kooperatyviai (kartelio sprendimas) aiškinamas kaip:

- noras pasiekti (komponento) Pareto efektyvų rezultatą,
- atpildo grėsmė,
- prekybos santykių kultūra, kuri palengvina derybų rezultatų harmonizavimą. Skatinimas spręsti nekooperatyviai, nes yra nuojauta, kad kitas dalyvis veiks nekooperatyviai.
- negalima laukti atpildo paskutiniame ture (baigiamojo žaidimo efektas).

Negalima daryti tikslių prognozių dėl prieštaringų skatinimų spręsti nekooperatyviai ir kooperatyviai.

7. Sutarčių stabilumas ir prognozės koopeticijos modeliuose su atskirais užsakovais

Aukciono procedūroje, kur dalyvauja pramonės tiekimo tinklas su dviem galimais tiekėjais, atskiras užsakovas ar koalicinė struktūra skiriasi tarpusavyje pagal tokius aspektus kaip:

- dideli ir maži kaštai, susiję su kooperacijos partnerių pakeitimu,
- išimtinai vieša informacija su galimybe gauti ir privačios informacijos.

Tuo atveju, kai dalyvio pakeitimo kaštai būna maži, naudojama OOCS taisyklė, kuri leidžia prognozuoti derybų rezultatą, o tai įgalina sudaryti stabilią sutartį, jeigu dalyviai bus racionaliai veikiantys. Ši taisyklė geresnė negu ADMCS taisyklė. Priešingai, tuo atveju, kai dalyvio pakeitimo kaštai būna dideli, Aumann-Dréze taisyklė leidžia daryti atitinkamą prognozę dėl pelno pasidalijimo tarp kooperuojančių pusių dėl to, kad kitas dalyvis bus negrąžinamai atmestas. Jeigu informacija apie dalyvių siūlomas maksimalias kainas yra privati, tai nuo to nenukenčia pelno paskirstymo taisyklių naudojimasis. Dalyvio pakeitimo kaštai gali būti dirbtinai generuoti pagal sutartį dėl ,,kontrakte numatytos bausmės".

8. Eksperimento rezultatai

Kalbant apie tiekimo tinklus, dirbančius su plačiąją rinka, surinktų eksperimento duomenų analizė leidžia daryti tokias išvadas:

- ,,Vidutinio bendro pelno vienam dalyviui“ palyginimas patvirtino, kad derybos daro teigiamą įtaką pelno vidurkiui.
- Palyginus ,,vidutinį pelną vienam dalyviui per vieną atskirą turą“ buvo iš dalies patvirtinta ir iš dalies paneigta teorinė prognozė, kad daugelio turų žaidimai duoda didesnį vidutinį pelną negu vieno turo žaidimai.
- Palyginus baigiamuosius turus iš 5 turų žaidimų su pateiktais pelno vidurkiais, pasitvirtino prognozė dėl vidutinio pelno sumažėjimo dėl ,,baigiamojo žaidimo efekto“.

Kalbant apie tiekimo tinklus, dirbančius su atskirais užsakovais, surinktų eksperimento duomenų analize buvo nustatyta, kad:

- tuose žaidimuose, kuriuose dalyvių pakeitimo kaštai buvo maži, pasirodė, kad OOCS taisyklė buvo tiksli ir ženkliai tikslesnė už ADMCS taisyklę.
- kai žaidimuose dalyvio pakeitimo kaštai buvo dideli, ADMCS taisyklė pateikė tikslias prognozes. OOCS taisyklės negalima naudoti tokiuose žaidimuose.

9. Galima praktinė tyrimo vertė

Disertacija, kaip tarpinis žingsnis mokslo plėtroje, prisideda prie:

- geresnės kontrolės vykstant deryboms,
- derybų rezultatų prognozės ir
- sutarties stabilumo esant skirtingoms aplinkybėms.

Ateityje įmonių turimos kompiuterinės sistemos duos reikiamus racionalius sprendimus, kurie svarbūs verslo strategijai.

Disertacija – tai indėlis šia linkme. Šia prasme disertacija apskritai padeda geriau suprasti strategijos valdymą ir savitarpio santykius versle.

Annexes[1]

Annex A. Coalition structures with 3 agents that are irrelevant for supply chains

Annex B. Supply chains with 2 and 4 agents

Annex C. Source codes – MATLAB and z-tree

Annex D. Empirical results

Annex E. Copies of scientific publications by the author on the topic of the dissertation

[1]The annexes are supplied in the enclosed compact disc

Harald David STEIN

MODELLING ENTERPRISE CO-OPETITION

Doctoral Dissertation

Social Sciences,
Economics (04S)

Harald David Stein

ĮMONIŲ KONKURENCINIO BENDRADARBIAVIMO MODELIAVIMAS

Mokslo daktaro disertacija

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