Game Theory Approach to Managerial Strategies and Value Creation

Diverse and Global Perspectives on Value Creation Set

coordinated by
Nabyla Daidj

Volume 3

Game Theory Approach to Managerial Strategies and Value Creation

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Introduction

This title is the prolongation of an idea initiated in our 2007 book on the bonds between game theory and strategic management theories [DAI 07]. Thus, the objective was to show how game theory could be useful for a firm engaged in formulating its strategy. The idea was to demonstrate through representative case studies of current issues in strategic management that game theory could be used to:

– provide an original analysis grid for the outcomes of a certain number of situations whose concrete results could be useful for managers (*ex post* analysis grids);

– provide managers with pointers in terms of strategic decision-making, allowing them to structure their line of thought around alternative – or at the very least, complementary – logics to the ones that emerge from their day-to-day work.

This first book caused reactions both in the academic world, during conferences, and in the "professional" world, during conventions or during the creation of case studies that began using this procedure. The concepts and tools developed within this first title were inspired by lessons from various courses with students of master's programs and various professional and academic profiles. The common denominator for this audience is generally the desire to acquire tools that stay relevant to the reality they are attempting to study. A technical presentation of game theory tools to this audience would be counter-productive. It is therefore preferable to work toward making these tools accessible. Managerial techniques need to be supported by real-world applications, but decisions must also be restructured around new methods of analysis. Game theory responds to the required intellectualization of real-world analysis provided that the primary lessons fit in with the reflexive tradition of strategic management theory.

Both the first and current study respect that philosophy through the association of two authors whose experiences and careers are different yet complementary. The first among them is an industrial economist, specialized in applied game theory (to various industries including agri-food), who, for a long time, focused on useable formulations of concepts of game theory for operational use. The second author is a strategic management specialist experienced in the analysis of themes from various sectors. Her expertise connects the more classic methods of her field with an openness to original methods of game theory.

This sort of pedagogical procedure, appearing in the first book, was presented and "tested" among different audiences and feedback has been positive overall.

These different elements encouraged us to develop this approach, especially considering that, since 2007, there has been an increasing interest in game theory explained by the changing and uncertain context and climate which businesses are developing in. This increased interest, beyond being a temporary trend, demonstrates the necessity of research tools capable of structuring this philosophy in contexts of interaction so complex that traditional tools prove to be insufficient.

A number of blogs, consultancy firms such as Capgemini (Box I.1) as well as various companies such as Orange (Box I.2), openly refer to game theory as a potential tool to help decision-making at a managerial level.

"How can a sourcing manager take tips from these games and use them to their advantage? By studying the bid patterns of suppliers during a negotiation, buyers can more effectively figure out the supplier's floor price. Buyers can navigate all possible scenarios of a negotiation outcome by applying game theory payoff matrices. Decide the desired outcome, and work your way backward to understand what would lead suppliers (if you believe them to be rational) to make these decisions. Understanding which tactics to use for each situation will help influence the supplier's decisions.

Capgemini has developed many approaches to help clients better predict and shape the competitive dynamics of procurement negotiations. Understanding game theory can help sourcing managers gain deeper insights into interests and objectives of suppliers, and ultimately influence the buyer's most desired outcomes".

Box I.1. *Game theory: an incursion into the world of consultancy? Extract from [MEU 14]*

"Car or public transport? Queen to A6 or knight to B3? Transmit information or keep it? Competition or cooperation? Game theory and its success helps us to answer these questions and many more!

What theory?

Game theory is a branch of mathematics that analyzes decision-making in humans, animals, machines or software, called *players*, which mutually influence one-another. The choices of player results in a situation known as *game outcome* which attributes each player a *gain* (e.g. time stuck in traffic). If one's choices affect another's and vice-versa, then they are part of a game!

But is this truly useful or not?

It is! In terms of applications, game theory has an impact on our society. It was used in the mid 20th century by the RAND Corporation to analyze the resolution of conflict situations in the context of a National Security program for the American government. Mechanism Design Theory (Nobel prize in economics in 2007 – L. Hurwicz, E.S. Maskin and R.B. Myerson) has met great success through its internet applications, in particular in online markets and auction places or for sponsored links. Stable paired games are used to design association mechanisms in certain binary markets such as financial aid for high-schools or hospitals […].

What should I take away from this?
Three things! First off, a game is a situation where the participants make decisions which will impact the other participants. There are many situations of this type. They are part of our daily life. Secondly, game theory attempts to mathematically formalize the analysis of these situations. The objective is to understand these choices, predict them and develop mechanisms to make decisions. Thirdly, it is a very successful theory particularly in the field of economics. It is also used in other fields such as biology and networks. The potential is vast and the development of this theory goes hand in hand with that of our world. Your turn next!"

Box I.2. *Game theory: whatever for? Extract from [TOU 17]*

Oderanti and de Wilde [ODE 10] highlight how certain business leaders have seized this subject, citing in particular the CEO of Coca-Cola:

> "In business games, the firm identifies the moves that the rival could make in response to each of its strategies. The firm can then plan counter-strategies (Griffitts and Wall, 2000). As Doug Ivester, Coca-Cola's president put it (Himmelweit *et al.*, 2001), 'I look at the business like a chessboard. You always need to be seeing three, four, five moves ahead; otherwise, your first move can prove fatal'. Game theory helps explore the impact of calculations about future market advantages on a firm's current market strategies". [ODE 10]

Since the early 2010s, there have been many references to game theory in relation to predictive analyses in digital transformation. Today, *big data*, something that is almost a daily headliner (in mainstream, specialist and academic media), refers to the processing of massive quantities of data (*data analytics*) and the associated predictions. The latter are techniques that rely on statistical tools, the search for correlations and game theory. The objective is to use present and past facts to formulate hypotheses on future events that can be helpful for assessing client risk, among other things (insurance companies, banks). In total, all of these novel tools will have an impact on decision-making and the company's value creation.

The market for predictive analysis software will reach $3 billion in 2017. Another huge trend at the moment is predictive analysis. According to IDC, it relies on statistics and game theory to analyze historical data and draw hypotheses for the future. It finds applications in practically all sectors and various fields: one of the more known applications involves client risk assessment. According to IDC, the market for predictive analysis software is currently 2 billion dollars and should pass 3 billion as early as 2017.

Box I.3. *Big data, predictive analysis and game theory [UMA 15]*

We must therefore look beyond applied game theory's predictive and decision-making ambition and see it as a "way of thinking". It allows reasoning in a rigorous frame of context that helps structure strategic considerations. Using its tools grants a better, or at least a different, understanding of interaction situations, going beyond a critical description of the situation parameters. The intellectualization of strategic thought associated with such situations of interdependence opens the way to rich and sometimes counter-intuitive developments of the analysis of concrete cases. We will demonstrate this in a number of examples throughout the book.

> "The question is to know what you want from game theory. If it's a solution, one must be rigorously mathematical. Now, if it is a way of thinking, or as suggested by Schelling, a learning framework, game theory places [the actors] within a context of common interaction […]". [SCH 08]

But furthermore, this book has another objective: to establish a gateway to the world of research.

Research in formalized economics and/or management (using mathematics) is often unable to unify the process among an uninitiated audience. It must be said that it rarely attempts to. Researchers often speak to researchers. And yet luckily, the issues they set out to study draw substance from real-world questions that the public will understand. But the technical developments that follow break that connection between research and the world of managers and students from non-specialist majors. From there, the second challenge for this book is to contribute to spreading current strategic research. It is a matter of revisiting industrial economics publications (agri-food, media, automotive, etc.) through the prism of applied game theory and extracting their substance: an intellectual procedure that can prove to be important to the structure of strategic considerations. The second part of the book, in particular, responds to that objective.

The book is divided into two parts that can be read independently one from the other. The first theoretical part (Chapters 1–3) recalls the primary concepts and tools of game theory. It integrates a number of examples of games that illustrate “simple” strategic deliberations that companies can experience when faced with various situations. The definitions of key concepts of game theory (equilibriums, caution, etc.) are presented in Appendices 1 and 2 and unfamiliar readers should refer to them to better understand basic concepts. The second part (Chapters 4–7) presents a number of case studies in a number of sectors. These studies are most often extracted from ongoing research studies reviewed and rewritten in a simpler game form.

1

Game Theory and Strategic Management

As has been previously mentioned in the Introduction, game theory has many fields of application. It has grown considerably, in particular in the fields of social science and economics. But its role in the field of management science still remains quite limited despite the interest it raises with certain authors, and even professionals. We look at the appearance of game theory in management science. We analyze the parallels between game theory and strategic management.

1.1. Game theory and strategic management: semantic and/or conceptual convergences?

Companies tend to adopt more than one strategy. But what do we mean by strategy? The notion of "strategy" has many different interpretations. As it is ubiquitous in the study of strategic management and of course in game theory, we compare these two disciplines. More generally, one of the major obstacles to a confrontation between game theory and strategic management exists within the many meanings it can hold (see Table 1.2). As is highlighted by [THE 98]:

> "[…] The fundamental notions – game, rules, strategies, etc. – do not refer to the same things in both fields".

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Let us begin with the notion of "strategy", originally a military term that appeared in the 1960s in managerial literature and the world of business. "Business strategy" appears in the works of [CHA 62] on the evolution of a number of large American companies as well as the works of [ANS 65] on strategic and operational decision-making. In 1965, "SWOT" (*Strengths*, *Weaknesses*, *Opportunities*, *Threats*) or LCAG (initialed after its Harvard authors: Learned, Christensen, Andrews, Guth) was defined as follows [LEA 65]: "It is the founding model of strategic management which highlights strategic analysis under two angles: external with the market (threats and opportunities) and internal with the firm (strengths and weaknesses)".

Authors	Definitions
[DRU 54]	"Strategy is analyzing the present *situatio*n and changing it if necessary. Incorporated in this is finding out what one's *resources* are or what they should be". [DRU 54, p. 17]
[MIN 79]	"Strategy is a mediating force between the organization and its *environment*: consistent patterns of streams of organizational decisions to deal with the *environment*". [MIN 79, p. 25]
[LEA 65]	"Strategy is the pattern of objectives, purposes or goals and major policies and plans for achieving these goals, stated in such a way as to define what businesses the firm is in or is to be in and the kind of firm it is or is to be". [LEA 65, p. 15]
[ANS 65]	"Strategy is a rule for making decisions determined by product/market scope, growth vector, competitive advantage, and synergy". [ANS 65, pp. 118–121]
[CHA 62]	"Strategy is the determination of the basic long-term goals and objectives of an enterprise, and the adoption of courses of actions and the allocation of resources necessary to carry out these goals". [CHA 62, p. 13]
[STE 77]	"Strategy is the forging of firm missions, setting objectives for the organization in light of external and internal forces, formulating specific policies and strategies to achieve objectives, and ensuring their proper implementation so that the basic purposes and objectives of the organization will be achieved". [STE 82, p. 19]

[POR 80, POR 85, POR 96]	"Competitive strategy is about being different. It means deliberately choosing a different set of activities to deliver a unique mix of value". [POR 96, p. 60] Porter's philosophy evolved over the years, and with it, his definition of strategy. In 1980, his first book defined the conditions for attractiveness in an industry and analyzed the generic strategies that allow a firm to reach its optimal position on the market. In 1985, he defined business strategy as follows: "the search for a favorable competitive position in an industry, the fundamental arena in which competition occurs. Competitive strategy aims to establish a profitable and sustainable position against the forces that determine industry". [POR 85, p. 42]
[RUM 91]	"Strategic management, often called 'policy' or nowadays simply 'strategy', is about the direction of organizations, and most often, business firms. It includes those subjects which are of primary concern to senior management, or to anyone seeking reasons for the success and failure among organizations. Firms have choices to make if they are to survive. Those which are strategic include: the selection of goals, the choice of products and services to offer; the design and configuration of policies determining how the firm positions itself to compete in product-markets (e.g. competitive strategy); the choice of an appropriate level of scope and diversity; and the design of organization structure, administrative systems and policies used to define and coordinate work". [RUM 91, pp. 5–6]

Table 1.1. *The primary definitions of strategy by the authors in strategic management*

The word "strategy" has inspired a number of authors and has therefore lead to a variety of definitions (Table 1.1). These can be classified according to certain criteria/logic (Table 1.2) specific to strategic management:

– firm–environment relation (external diagnosis);

– resources–competencies (internal diagnosis of the firm);

– resource allocation

Table 1.2 presents a number of definitions of certain key terms including game, strategy, competitive advantage, value creation and strategic decisions. The "x" sign indicates that the definition belongs to the field in question.

In game theory, the word "strategy" once again refers to a number of different meanings. For [SCH 86], strategy mainly refers to an interdependency between opponents' decisions. Each player must define his or her own behavior according to his or her counterpart's behavior. The author defines the concept of "strategy" in reference to the means allowing one player to force his or her opponent's decision by acting on the latter's perception of the consequences of his or her own actions. Shubik [SHU 64] engages a similar definition as he considers that:

> "in regards to economic competition, it can contain conditional actions where choices depend on decisions by rival businesses. In practice, there are too many possibilities to be explained, but in theory a strategy specifies the action a player should choose for each possible movement so that he can anticipate that of his opponent's".

Definitions	Strategic management	Game theory
Game		
"Any economic decision contains an important 'game' aspect to it due to the general context in which it exists ('conjuncture' and its side-effects), of the influence it can have on the near environment of the decision-maker and the effects it can expect in return". [GUE 97]	x	x
Competitive advantage and value creation The objective of a strategy is "to respond to the expectations of the involved parties, to obtain a competitive advantage and create value for their clients". [JOH 01]	x	The notion of competitive advantage does not exist as such but refers to the notion of "best response" (the most satisfactory strategy) for a firm to obtain the highest "payoff" compared to its competitor(s). The notion of value is eclipsed by the notion of "payment" (gain).

Activity portfolio and resource allocation in a long-term perspective There could be no strategy if the resource allocation does not sustainably engage the future of the firm [ANA 85]. Strategy consists of a "resource allocation which engages the organization in the long-term by configuring its perimeter of activity". [JOH 01] "Elaborating the firm strategy is choosing the field of activities in which the firm intends to be present and allocate the resources in such a way that it persists and develops there". [STR 04]	x	There is no equivalent to the activity portfolio in game theory: the firm is often confronted with strategic choices surrounding a particular activity. The long-term perspective refers to different notions linked to the repetition (or lack thereof) of games and the infinite horizon.
Primary characteristics of strategic decisions		
They are complex.	x	x
They are made in a situation of indecision.	x	x
They must account for the internal situation of the firm.	x	
They must account for the environment of the firm.	x	x
They require important changes.	x	x
They affect the operational decisions.	x	

Table 1.2. *The strategy and strategic decisions at the heart of game theory and strategic management: what correspondences?*

One important distinction must also be made between the notions of strategy and that of movement [VIC 85]. Strategy differs from movement, which corresponds to the action taken by a player in the face of a given situation, whereas strategy encompasses all means of response at the players' disposals when facing an eventuality. A strategy specifies all possible actions that a player may take.

> "To anticipate other players' reactions to your actions, you have to put yourself in their shoes and imagine how they'll play the game. You look forward into the game and then reason backwards to figure out which initial move will lead you to where you want to end up". [BRA 97]

Game theory focuses on the relations between a firm and its environment. This predominant relationship "firm (player) – environment" in game theory gives us the opportunity to schematically restate the two complementary approaches that exist in the field of strategic management and that explain the sustainable competitive advantage of a firm or, conversely, its difficulties and problems positioning itself on the market:

– an "external" analysis of the environment calling upon different analysis models, including Porter's five forces model[1];

– an analysis of the "resources and competencies" that conversely insist upon a firm's ability to use and shape its environment because of its most advantageous resources and its core competencies in play [BAR 91, WER 84]. The analysis of a firm's strategic capability then depends on three essential factors. This is why the notion of resources is often associated with the notion of organizational abilities, which refers to a firm's routine, its expertise and its processes. The third element is the balance between resources – a notion that brings us back to that of strategic business units (SBUs) in order to achieve the most complete vision of the firm's strategy allowing it to judge definitively the equilibrium (or imbalance) of the activities portfolio.

The dimensions of "internal diagnosis" (assessment of resources and competencies) specific to strategic management do not appear upon first glance in game theory. As specified in [GUE 97]:

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1 Since its appearance, this five forces model has in fact brought about a number of studies and the addition of a sixth force that successively refers to the roles of public authority (the most generally accepted version) and to innovation. Other authors even refer to complementors according to Brandenburger and Nalebuff's [BRA 95, BRA 96] terminology.

> "A firm's decision – whether it concern purchasing, selling, hiring, investing, etc. – must take into account not only the situation of the society in which it exists, but also and perhaps most importantly, of its close environment – meaning everyone that it is in close contact with (employees, suppliers, competitors). And yet, it is above all these relations with this environment that interest us in game theory; it is true that is does not exclude external effects, but it wants to first go to the simplest option and concentrate exclusively on the interactions and decisions between players – thus eliminating any form of uncertainty other than that which results from the players making decisions".

1.2. The current position of game theory in strategic management

1.2.1. *Game theory and the school of positioning*

In their book *Strategy Safari*, [MIN 99] present a complete panorama of the theories of strategic management by grouping them into 10 "schools of thought": the design school, the planning school, the positioning school, the entrepreneurial school, the cognitive school, the learning school, the power school and the cultural school, the environmental school, the configuration school.

They classify these schools into three groups (see Table 1.1):

– the first three schools are normative;

– the following six schools are more descriptive: they aim to describe the veritable processes involved in creating a strategy;

– the last group only includes one single school even though, according to Mintzberg *et al.* [MIN 98], it actually encompasses all the others.

Procedures	Schools	Themes
Prescriptive approach	Design school	Creating a strategy through a design process. It mainly relies on the SWOT model aiming for harmony between internal forces and external opportunities and threats. The notions of strategic alignment (*fit*) and key success factors (KSFs) are underlying. *This approach is more concerned with how strategies should be formulated than with how they necessarily do form. It regards strategy formation as a process of conception, matching the internal situation of the organization to the external situation of the environment. Thus the strategy of the organization is designed to represent the best possible fit.*
Prescriptive approach	Planning school	The idea is to plan the actions performed by a firm in a bid to reach its goals. Strategy is considered as a formal process that must follow a number of predefined steps. It implies long- and medium-term strategic plans but also operational programs through SBUs. Scenario analysis fits into that logic.
Prescriptive approach	Positioning school	Creating a strategy using an analysis process. This school is often referred to as Porter's school. The works by consultancy firms (BCG, McKinsey) are also integrated into this current. Companies must find a way to improve their competitive position in the marketplace. The positioning school considers that there only exists a few key strategies (comparable to positions on the market) desirable in a given sector likely to be supported against current and future competition.
Descriptive approach	Entrepreneurial school	Creating a strategy through a visionary process. The personality of the leader becomes a key element and his or her charisma and vision contributes to the success of the firm. This philosophy focuses particularly on start-ups operating within a particular context, on companies operating within niche markets or on companies currently under administration.

Descriptive approach	Cognitive school	Creating a strategy using a mental process. "Certain important authors have long associated strategy with *firm spirit*, which they define as the creation of a vision by a great leader. Yet, while a strategy can be a personalized vision, its creation must also be considered as the mental process which leads this individual to this vision. Thus the appearance of another small yet important school, which uses cognitive psychology to penetrate the mind of the strategist". [MIN 09, p. 8]
Descriptive approach	Learning school	Creating a strategy via a latent emerging process. Due to the complexity of the world in which companies evolve, strategy is created progressively day after day at the rate of the companies' adaptation or rather as it "learns". Companies are capable of learning from their own experience. Learning is both individual and collective.
Descriptive approach	Power school	Creating a strategy via a negotiation process whether between opposing groups within the same firm or between the latter and its exterior environment.
Descriptive approach	Cultural school	Creating a strategy as a collective and cooperative process rooted within the firm culture.
Descriptive approach	Environmental school	Creating a strategy as a reactionary process originating from an exterior context rather than within the firm. Analyzing the pressures exerted upon the firm.
	Configuration school	Creating a strategy as a transformation process. "Partisans of this theory attempt to assemble and integrate the different elements […] – the strategic development process, the content of these strategies, the organizational structures and their context – in distinct stages of firm growth or maturity, for example, sometimes placed in chronological order to describe a firm's life-cycle. But if these settle into stable states, the creation of a strategy must be able to describe the passage from one state to another. This is why one aspect of this school conceives the process as a transformation that integrates a great deal of the normative literature and practices relating to "strategic change". [MIN 09, p. 9]

Table 1.3. *The 10 schools of strategic thought according to [MIN 09]*

In this work, [MIN 09] did not pull punches when critiquing each one of these strategic schools of thought, but they did attempt to present a number of authors and identify theories that are not necessarily mainstream.

> "For the most part, the teaching of strategic management has highlighted the rational and prescriptive side of the process, namely our first three schools (design, planning, and positioning). Strategic management has commonly been portrayed as revolving around the discrete phases of formulation, implementation, and control, carried out in almost cascading steps […]. Significant space is given to the non rational/non prescriptive schools, which point to other ways of looking at strategic management. Some of these schools have a less optimistic view about the possibility for formal strategic intervention. Where we become unbalanced somewhat is in our critiques of the different schools. The three prescriptive schools have so dominated the literature and practice that we find it appropriate to include rather extensive discussions that bring much of this conventional wisdom into question. Of course, we critique all ten schools, since each has its own weaknesses". [MIN 09]

[MIN 09] recognize that different great philosophies of strategy only explain part of the strategic management process. There is no global synthetic vision. We are all blind standing before an elephant we call "strategy formation". Each one of us only perceives part of the animal and still attempts to get a general and unique idea of what the animal may look like (Box 1.1). The authors reused the ancient metaphor of "the blind men and the elephant" from Jainist tradition (India) and translated to English by John Godfrey Saxe (1816–1887).

THE BLIND MEN AND THE ELEPHANT

by John Godfrey Saxe (1816–1887)

It was six men of Indostan
To learning much inclined,
Who went to see the Elephant
(Though all of them were blind)
That each by observation
Might satisfy his mind.
The First approached the Elephant,
And happening to fall
Against his broad and sturdy side,
At once began to brawl:
“God bless me but the Elephant
Is very like a wall.”
The Second, feeling of the tusk,
Cried, “Ho! What have we here
So very round and smooth and sharp?”
To me “tis mighty clear
This wonder of an Elephant
Is very like a spear!”
The Third approached the animal,
And happening to take
The squirming trunk within his hands,
Thus boldly up and spake:
“I see,” quoth he, “The Elephant
Is very like a snake!”
The Fourth reached out an eager hand,
And felt around the knee,
“What most this wondrous beast is like
Is mighty plain,” quoth he;
“Tis clear enough the Elephant
Is very like a tree!”
The Fifth, who chanced to touch the ear,
Said: “E’en the blindest man
Can tell what this resembles most;
Deny the fact who can,
This marvel of an Elephant
Is very like a fan!”
The Sixth no sooner had begun
About the beast to grope,

Than seizing on the swinging tail
That fell within his scope,
"I see," quoth he, "the Elephant
is very like a rope!"
And so these men of Indostan
Disputed loud and long,
Each of his own opinion
Exceeding stiff and strong,
Though each was partly in the right,
And all were in the wrong!

Moral
So oft in theologic wars,
The disputants, I ween,
Rail on in utter ignorance
Of what each other mean,
And prate about an Elephant
Not one of them has seen!

Box 1.1. *The tale of the blind men and the elephant*

The authors make a short allusion to game theory by placing it in the positioning school.

> "Most notable in this school has been one simple and revolutionary idea, for better and for worse. Both the planning and design schools put no limits on the strategies that were possible in any given situation. The positioning school, in contrast, argued that only a few key strategies – as positions in the economic marketplace— are desirable in any given industry: ones that can be defended against existing and future competitors. Ease of defense means that firms which occupy these positions enjoy higher profits than other firms in the industry. And that, in turn, provides a reservoir of resources with which to expand, and so to enlarge as well as consolidate position". [MIN 09]

It is interesting to note that Porter's works also appear in the positioning school (value chain, five forces framework, etc.), which use the environment as a referential.

1.2.2. *Growing interest for game theory*

As far back as the 1980s, Porter was making references to game theory, thus positioning himself in line with authors of the Industrial Organization (IO) movement. Porter emphasizes the fact that the firm must adapt to its environment and research favorable and lucrative sectors, meaning sectors that are characterized by a relatively weak competition. This approach to competitive dynamics [POR 82, POR 86], which places the environment at the center of a firm's strategy, is an idea that comes from IO. Most of the other IO concepts also make an appearance: barrier to entry, differentiation, etc. The first models developed within the frame of strategic management therefore largely found their origins in IO.

Porter mentions game theory in the very introduction of his first book, *Competitive Strategy*, in these terms: "Market signaling, switching costs, barriers to exit, cost versus differentiation, and broad versus focused strategies were just some of the new concepts explored in the book that proved to be fertile avenues for research, including the use of game theory". Throughout the rest of the book, Porter cites numerous references to game theory as is explained by [JÖR 08]:

> "Beyond industry analysis, Competitive Strategy also offered insights on the scope of the firm, on game theory applications to strategy, and on competitor analysis. Chapter 14 on vertical integration explored both the advantages and disadvantages of backward and forward integration in different industry contexts. Chapter 4 on market signals (4) and chapter 15 on capacity expansion (15) applied game theory concepts to competitive strategy: credible threats, retaliation, commitment, reputation, trust, pre-emption, rational versus irrational stances, and signaling. The model for competitor analysis

> (Chapter 3) explores how a rival's capabilities, assumptions, future goals and current strategy affect its response profile. The model includes the rival's current competitive strategy, but goes well beyond this to examine cognitive factors (assumptions of the rival), motivation (future goals) and resources (capabilities)".

At the beginning of the 1990s, even though Porter [POR 91] was not publishing books and articles explicitly about the possible links between game theory and strategic tools, he did favor a dynamic approach to strategic management once again insisting on the potential benefits of game theory:

> "How […] do we make progress towards a truly dynamic theory of strategy? Scholars, in both strategy, organizational behavior, and economics, sensing this as the frontier question, have made some headway. There are three promising lines of enquiry [Game Theory, the Resource-Based View and Commitment & Uncertainty Research] that have been explored in recent years. Each addresses important questions, though focusing on a somewhat different aspect of the problem. […] The first line of inquiry is the proliferation of game theoretic models of competitive interaction, referred to earlier, which seek to understand the equilibrium consequences of patterns of choices by competitors over a variety of strategic variables such as capacity and R&D. These models have helped us understand better the logical consequences of choices over some important strategy variables. In particular, these models highlight the importance of information and beliefs about competitive reaction and the conditions required for a set of internally consistent choices among rivals".

Independently of Porter's work, the first notable "intrusions" of game theory in strategic management were to be found in the works of [DIX 91, DIX 99, MAC 92, MIL 92] and [BRA 95, BRA 96, BRA 97]. These authors were convinced of the role that game theory could have in the field of strategic management. Based on game theory, [BRA 97] have developed a set of guidelines that will "make it easier to explain the reasoning behind a proposed strategy". By using game theory, managers can elaborate various strategies and then choose the best one.

> "Game theory expands your strategic palette by facilitating the identification of players and interdependent relationships between them. […] It helps you to assess the envisaged changes with great assurance using exhaustive methods at hand. It encourages you to understand the viewpoints of other players and understand the reactions they may have in regards to future strategies. From this global vision, a strategic ensemble of richness and reliability arises". [BRA 97]

[GRA 02] considers that game theory contributes toward creating a frame that makes it possible to better understand the strategic decisions and determine optimal strategic solutions:

> "Game theory has two especially valuable contributions to make to strategic management: 1) it permits the framing of strategic decisions. Apart from any theoretical value of the theory of games, game theory provides a structure, a set of concepts, and a terminology that allows us to describe a competitive situation in terms of identity of the players, specification of each player's options, specification of the payoffs from every combination of options, the sequencing of decision using game trees; 2) it can predict the outcome of competitive situations and permits the selection of optimal strategic choices". [GRA 02]

However, despite these early appearances, references to game theory in strategic management textbooks remain limited. This absence can be explained with the perceived complexity of game theory by authors from the field of strategic management, as [CAM 91] mentions:

> "I distinguished four problems to make strategy researchers tread carefully in their use of game theory: a

> chopstick problem (game-theoretic models are too hard to use); a collage problem (the models form an incoherent collage, suggesting no general principles); a testing problem (the models are hard to test); and a Pandora's box problem (the models can explain anything). The chopstick problem can be overcome by education, practice, and (possibly) by software. The collage problem and the testing problem present opportunities for empirical strategy research to test game theories in a unique way, but only if researchers turn from broad cross-sectional tests to more specialized longitudinal studies with finer-grained observation. The Pandora's box problem will take theoretical discipline and empirical constraint – supplied, perhaps, by strategy research".

As we will see in the following section, other authors "popularized" game theory for a strategic context. The concept of coopetition, in particular, allowed for certain applications of game theory. The use of this concept allowed a limited need for mathematical tools and helped popularize certain mechanisms of game theory.

1.3. The theoretical determinants of coopetition: borrowed from game theory

1.3.1. *The origin of coopetition*

The number of novel concepts associated with strategic management has grown exponentially in recent years. This profusion of concepts and vocabulary illustrates the increasing complexity of the context in which companies now evolve and the difficulties associated with strategic decision making in an uncertain environment. Each decade is marked by the emergence of a novel concept/tool, the "notoriety" of which can or cannot last long (see Table 1.4). Strategy has evolved at the instigation of both academics and professionals.

"Coopetition" can thus be considered a relatively recent concept. According to Walley [WAL 07], the origin of the term "coopetition" is unclear. Albert [ALB 99] considers that the term appeared in 1991, but there are many others who believe the word is attributed to the firm Novell, which first used the word in the 1980s.

Period	Primary concepts	Authors
1950s	Management by objectives (MBO)	[DRU 54]
1960s	Chandler: strategy follows structure The Ansoff matrix SWOT analysis: strengths, weaknesses, opportunities, threats	[ANS 65, CHA 62, LEA 69]
1970s	The McKinsey Matrix (1970–1975) The Boston Consulting Group (BCG) Matrix *Profit Impact of Marketing Strategies* (1960–1980): strategic analysis initiated in 1960 at General Electric aiming to explain the profitability of cross-referencing a large number of criteria	Consultancy firms (BCG, Mc Kinsey, AD Little)
1980s	Value chain Resource-based view (RBV) Strategic intent Profit models	[BAR 91, HAM 89, HAM 93, HAM 94, POR 80, POR 85, SLY 88, WER 84, WER 89,]
1990s	Hypercompetition coopetition, value network The 10 schools of thought on strategic management Disruption: disruptive technologies Long tail Knowledge management (KM)	[AND 04, BEN 03, CHR 00, DAV 94, DAV 98, MIN 98, MIN 98, NAL 96, NON 95]
2000s	Blue ocean, red ocean strategies Business ecosystems Keystone advantage Business models Open innovation Platform economies Lean start-up	[AFU 00, AMI 01, CHE 03, GAW 02, GAW 08, HAG 15, IAN 04, KIM 05, MOO 06, OST 09, RIE 08, TIM 98]
2010s	Shared value Transient advantage	[MCG 13, POR 11]

Table 1.4. *Evolution of concepts: a couple of emblematic examples (adapted from [DAI 15])*

This notion of coopetition, that is relatively complex, refers to various levels of analysis. [DAG 07b] suggest studying the concept of coopetition on three levels: macro-economic (country, companies), meso-economic (cross-firm relations, supplier relations) and micro-economic (firm, groups, individuals, companies).

> "Far from being a compact monolith, coopetition strategy is a multidimensional and multifaceted concept which assumes a number of different forms and multiple levels of analysis and for which it is all but easy to grasp its structure, processes and evolving patterns". [DAG 02]

1.3.2. *Coopetitive practices*

It is mainly the innovative works of [BRA 95] and [BRA 96] that paved the way for the convergence of game theory with strategic management through coopetitive practices.

> "In its purest form, business can be considered as a game in which money represents points won or lost. The person or firm which gathers the greatest numbers of points wins. The biggest opportunities in business don't come from playing the game better than everyone else – they come from changing the fundamental nature of the game itself to your advantage. Business strategy, and the concept of co-opetition, is designed to provide a framework by which companies can gain a sustainable competitive advantage by changing the game to their own advantage". [BRA 96]

These authors are convinced of the need for more frequent use of game theory in decision-making processes. They present different cases of companies that have called upon it to make decisions – illustrations that have widely been reused in "strategic" literature. They cite the case of General Motors. The 1990s were looking rough for the three automotive manufacturers (General Motors, Ford and Chrysler), then confronted with a fierce pricing war leading to colossal losses for each of them. The game is "locked" until the announcement from General Motors to offer a credit card (GM Card) that would allow its owners to benefit from a certain number of advantages: access to a credit equivalent to 5% of purchases made with the card (by accumulating points) usable for the acquisition of a new vehicle from General Motors. The operation was an unprecedented success in terms of credit. The other manufacturers adopted the same loyalty strategy, which limited the price war. The proliferation of these types of credit cards discouraged manufacturers from lowering their prices as each price rebate attracts fewer customers. Lastly, the high initial cost of a credit card launch represented a "credible commitment" in favor of mutual cooperation along the terms of game theory. This commitment has consisted of favoring customer retention rather than increased business.

As shown in Table 1.5, many works [BAG 01, DAG 02, DOW 96, GNY 01, GUL 98, GUL 00, HAK 02, LAD 97] cover the emergence and the development of coopetition, defined as a situation in which competing companies simultaneously compete and cooperate among themselves [BEN 03].

Challenge/stakes	Authors	Definitions
It is a "mix" between cooperation and competition	[BEN 03, LAD 97]	"Coopetition is a situation in which rival companies (two or more) simultaneously compete and co-operate with each other". [BEN 03]
Strategic alliances versus coopetition?	[LUO 07]	"The delimitation between strategic alliances and coopetitive practices remains very unclear. Coopetition is often considered as an 'extension' of co-operation (in the form of agreements, alliances, strategic alliances) between companies. 'Coopetition and strategic alliance are connected with each other'. Establishing an alliance with competitors emphasizes cooperation only. Its unit of analysis is the alliance itself rather than the parent organizations. Alliances between competitors represent only a part of cooperative endeavors; they cannot reflect the effects of comprehensive competition on a diverse list of products between rivals, nor the insights of other types of cooperation such as collective efforts in lobbying governments, establishing industry standards, or building global or regional clusters of production and supply". [LUO 07, p. 130]

Environment		
Convergence technology/ innovation	[GNY 11]	"Coopetition is more critical in high technology contexts because of several challenges such as shrinking product life cycles, need for heavy investments in R&D, convergence of multiple technologies, and importance of standards". [GNY 11, p. 650]
The nature of coopetitive relations		
Motivations Benefits Goals	[DAG 07b]	Coopetition refers to a "system of actors interacting on the basis of a partial congruence of interests and objectives". [DAG 07b, p. 87] Access to distinctive resources and fundamental capabilities.
Level of coopetition	[ARS 08]	Coopetition can be observed at different levels: local, regional and national
Dyadic relations versus network	[DAG 02]	"The typology of interfirm coopetition is based on two basic coopetition forms: i.e., dyadic coopetition and network coopetition".
Static versus dynamic relationship Stable versus unstable vision	[GNY 11, LUO 07, MEL 07 PAR 96,]	The very nature of coopetition is dynamic: the cooperative and competitive do not remain constant throughout time [LUO 07]. "Dynamics of co-opetition would be (thus) shaped by industry and partner conditions as well as firms' capabilities to pursue a win-win approach". [GNY 11] Coopetitive relationships are unstable [PAR 96]. Difficulties in managing coopetive relationships as they are difficult to maintain and may lead to open conflict [MEL 07].
Trust	[MOR 07]	"Coopetition is a relationship which is characterized by trust, engagement and mutual benefits […]. Coopetition produces a unique context for trust, in that a firm must trust its partner in two quite different arenas […]. A coopetive partner develops trust regarding how the other firm will share resources, communicate, meet deadlines, use information, and other aspects of the cooperative dimension of the relationship". [MOR 07]

Results/performances		
Value	[DAG 02]	Coopetition is a strategy that simultaneously creates value and competition in the way that value is distributed
Profit	[ALB 99, CRI 02, LUO 05, PEL 98, WAL 07]	Coopetition can be used as a strategy that allows a firm to make profit and maximizes resources in a long-term perspective.
Applications	[DAI 15, DAI 11, DAI 16, DVO 06]	ICT sector (telecommunications, consumer electronics, media, video games, etc.)

Table 1.5. *The different definitions of coopetition (established by the authors on the cited work base)*

1.3.3. *Mechanisms of value creation in the value network (value net)*

As we have mentioned previously, we generally use game theory either to analyze market structures, or to study the behaviors of different actors (states, institutions, regulatory bodies, companies, etc.) through the formalization of their agreement, coalition or rivalry process. In that frame of analysis, the games are situations of strategic interdependence (with two or more players) through which different interests (if not opposing) are confronted.

In the "real world", the players are interdependent companies (or countries): each of their behaviors has an effect on the others and the best plan of action for one single firm depends on the strategies adopted by other rival companies. This attitude of each firm will be determined depending on the actions of its rival firms. This situation corresponds to a game that is therefore characterized by an interdependence between the different agents (players) that can induce situations of conflict or cooperation. This is the reason why [BRA 96] have drawn from this corpus to analyze the concept of coopetition.

[BRA 96] have adopted the mechanisms of game theory (cooperative games) to analyze the following:

– the value created by a specific actor “defined as the value created by all the players in the vertical chain minus the value created by all the players except the one in question” [BRA 96];

– the creation of asymmetries between companies. [BRA 96] introduced the notion of complementors and suggested adding actors in a new model as shown in Figure 1.1. The classic examples of “complementors” are those of a firm whose products require being combined with others to be used: *hardware* and *software*;

– the creation of value. [BRA 96] insisted on the necessity to create and capture the value created by *vertical chains* composed of suppliers, companies and clients. This notion of a *vertical chain* refers more to the notion of a sector that can be defined as a set of activities, upstream and downstream, linked between one another by complementary activities. This vertical representation must not be confused with the value chain. The former can be defined on two levels: the firm level (with support activities and operational activities) and the sector one. The value chain for a sector refers to the position of different actors and their capacity some of them to exert the coordination of activities and control throughout the chain (Table 1.6).

Concept	Definitions/primary characteristics	Firm level activity sector
Firm value chain	It is an operational chain analyzed from the point of view of the operators, in an objective toward creating value.	Firm
Sector value chain	It is a detailed cartography of the actors within a specific value chain. It allows one to better understand the position of companies in a given sector.	Industry
Cost chain	The cost chain is governed by the steps of a transformation, the production and distribution. A cost chain gives an insight into the interactions between the evolution of costs and the prices set by the market.	Firm/industry
Value system	The value system provides understanding for a sector of activity by decomposing all value creation activities within that sector into different value chains. The value system is often confused with the production sector.	Industry

Sector	The sector is a succession of transformation operations concluding in the production of a good (or set of goods); the definition of these operations is influenced by the state of ongoing techniques and technologies […]. Used at a number of levels of analysis, the sector appears as a system more or less able to ensure its own transformation [MOR 91, p. 269]. The sector can also be defined top-down as a set of activities, linked between one another by complementary activities (purchasing and selling intermediary consumptions).	Industry
Value network (Value net)	In a general sense, the value network refers to a network in which a firm evolves and the interactions it has with other stakeholders and the role they play. The notion of value network has been developed by Christensen [CHR 97] in the context of his works on disruptive innovation. This notion has been used to explain the links between the different actors in e-commerce. "In order to contribute to defining the firm mission it makes sense to use the concept of value network" [JOH 08]. "Overall, the idea is to determine how the firm will attempt to situate itself between the manufacturer and the end client. In matters of e-commerce, the question is closer to whether the business focuses on buying/ selling products, which assuredly constitutes the core of any commerce, or if firm decides not to buy and resell, to dedicate itself to something else, or even if the firm decides to position itself differently in a value network on top of buying/ reselling". [ISA 11, p. 15] The value network has taken on a more specific meaning in the literature surrounding coopetition (see the development of coopetition in this chapter).	Industry

Table 1.6. *Synthesis of the primary concepts: value chain, cost chain, value and sector system (established by the authors cited in the list)*

But the notion of *vertical chain* also refers to the interdependences between all the actors whose strategies can evolve; the different companies that can play a variety of roles depending on the situations passing from the complementor to the competitor (substitutor) describing a context of coopetition. Coopetition is a convergence of interests between "complementors", which appear when competition and cooperation occur simultaneously [DAG 07].

"Along the vertical dimension of the Value Net, there is a mixture of cooperation and competition […]. Along the horizontal dimension, however, managers tend to see only half the picture. Substitutors are seen only as enemies. Complementors, if viewed at all, are seen only as friends. Such a perspective overlooks another symmetry. There can be a cooperative element to interactions with substitutors". [BRA 95]

"The vertical dimension designs the firm's suppliers and customers (two of the five forces identified by Porter) and along the horizontal dimension are the players with whom the firm interacts but does not transact. They are its substitutors and complementors. Substitutors are alternative players from whom customers may purchase products or to whom suppliers may sell their resources […]. Complementors are players from whom customers buy complementary products or to whom suppliers sell complementary resources […]. The Value Net describes the various roles of the players. It's possible for the same player to occupy more than one role simultaneously". [BRA 95]

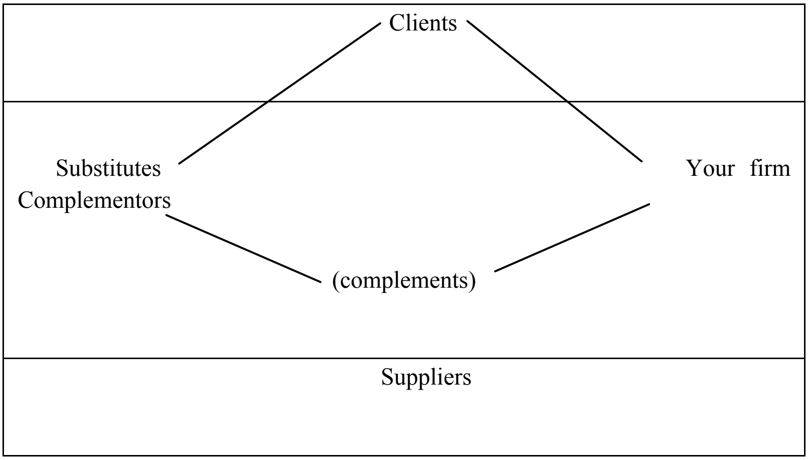


Figure 1.1. *Who are the actors in a value network? (adapted from [BRA 95])*

1.4. Conclusion

In the following chapters, we will try to demonstrate the reach of game theory (Chapters 2 and 3) and its possible applications to strategic management throughout various illustrations relative to the strategy of companies within different sectors of activity (Chapters 4–7).

Game theory serves to explain the mechanisms linked to strategic behaviors (social, economic, political, etc.). The economic spheres of intervention are plenty if we look at it from the firm's perspective. From the top-down, the firm must decide, for example, to train its staff (or not) in the presence of a competitor showing poaching habits. Training increases productivity, but requires financial investment. Therefore, there will always be arbitration. Furthermore, downstream, game theory concerns all decisions surrounding pricing, production, publicity level, localization of activities, relations with suppliers, entry onto the market, absorption policy by competitors, etc.

In the following chapters, we will present non-cooperative- and cooperative-type games (Nash); the first are zero-sum with individualist actors who play depending to their only interest; the second are non-zero-sum in which consultation is desired, thus alliance and coalition practices.

2

From Static Games to Dynamic Approaches

2.1. Introduction

In this chapter, we present static games and repeated games.

In the frame of non-cooperative games, games that are said to be static are the ones where players make one single simultaneous decision. The number of players is supposedly finite as well as the number of strategies in place. We are therefore placed in a *finite strategic space.*

This chapter also approaches the subject of "repeated" games, "games with multiple turns". These are specific cases of sequential games for which we can use specific resolution methods such as backward induction, which has been defined further along. It is the number (finite or infinite) of parties involved that then becomes a key element conducing to different solutions, some of which correspond to situations that would not be possible in a more static frame. When a game is repeated several times (in particular with an infinity of parties), it fits itself into a history where the notions of threats (reprisals), promises and commitments then begin to make sense and help with certain new solutions that we would not see in static games.

Game Theory Approach to Managerial Strategies and Value Creation,
First Edition. Abdelhakim Hammoudi and Nabyla Daidj.

2.2. Strategies and solution concepts: static games

Games allow us to informally state solution concepts among which are equilibrium dominant strategies, the solution obtained following the iterative elimination of strictly dominated strategies (which we will later see are part of Nash equilibrium) and the Minimax equilibrium. Nonetheless, these solutions do not concern all games and are therefore not always applicable. Game theory leads to a wider panel of solution concepts among which Nash equilibrium is the most common. Reaching a Nash equilibrium through best-response functions is a way to draw practical lessons surrounding the mechanisms of managerial decision-making in certain specific contexts.

2.2.1. *Decentralized concepts*

In this section, we introduce resolutions to basic games by defining some fundamental concepts. These given concepts can be used to solve particularly simple games. If the game is simple enough (when the matrix has certain characteristics that we will see later on), we can attribute each player a strategy without even knowing what his or her opponent is likely to do.

2.2.1.1. *Relationships of strategic dominance, strict dominance and weak dominance*

Here, we start to look at games that are relatively easy to resolve using the process of elimination of certain actions. Companies are often confronted with situations they consider complex and which open up to a number of possible responses, making the decision-making process particularly difficult. Yet, if we look closely at the results of the interdependencies (given by the outcomes) on a market, companies can quickly realize that certain strategies should never be used as they would result in lower gains than other strategies, no matter the opponent’s choice. This way, because of preliminary work, the strategic decision for a firm can be considerably simplified by the fact that it must be made amidst a reduced number of options.

The consideration process of the "strategist" (firm) can therefore be reduced to different phases, the first of which involves examining "the space of possible strategies" to see if it cannot be reduced to a smaller panel of decisions. This first step directly refers to the notion of *domination of one strategy over another*.

A strategy s_i of a player i (s_i being one of the possible strategies of i) is dominated by another of these strategies t_i (t_i being taken into account in the same set of strategies of i) if no matter the prediction he or she makes of the other player's strategy, player i realizes that it is still better (or the same) for him or her to play t_i rather than s_i.

In other words, if player i plays s_i, no matter the strategy used by the other player, the former will realize upon the outcome of the game that it would have been better for him or her to play t_i.

We will also say that t_i dominates (strictly or weakly) strategy s_i. If a strategy is dominated (non-strictly) by another, it means that the other offers a higher or equal reward. A non-strict dominance is known as a weak dominance.

If a strategy s_i by player i is strictly dominated by a strategy t_i for the same player no matter the strategy played by his or her opponent, the first player will always gain more by playing t_i rather than s_i (or any other strategy from that strategy space in general).

If there exists a strategy that belongs to the strategy space of a player that dominates (strictly or weakly) all other strategies for this player, we say that strategy is dominant (weak or strict). One strategy is therefore said to be dominant if it leads to a superior outcome in comparison with all other strategies, no matter the choices made by other players.

In the case where one player only has two possible strategies at his or her disposal and one of them strictly dominates the other, the first is *de facto* strictly dominant. This dominant strategy and only that one will be played.

To illustrate the notion of dominance, the following example is presented. Suppose that the gains associated to each outcome of the game are given by the following matrix:

		Entreprise 2 (E2)		
		H	B	D
	H	(10,10)	(20,5)	(12,6)
Entreprise 1 (E1)	B	(5,20)	(2,2)	(4,8)
	D	(6,12)	(8,4)	(13,13)

Firm 1 has a strictly dominated strategy (SDS): strategy B. More specifically, strategy B is strictly dominated by H as well as by D. How do we pick one? E1 does not know what E2 will play. On the other hand, it knows that:

– if E2 decides to play H, then H or D would be the best option rather than B (as they would yield 10 or 6, respectively, *rather than* 5);

– if E2 decides to play B, then H or D would be the best option rather than B (as they would yield 20 or 8, respectively, *rather than* 2);

– if E2 decides to play D, then H or D would be the best option rather than B (as they would yield 12 or 13, respectively, *rather than* 4).

This method is called strategy-by-strategy inspection that involves looking at *n* (number of possible strategies for firm 1) and *m* (number of possible strategies for firm 2). In our example, this means observing three strategies (B, D and H) for each of these companies and representing them in a single matrix that corresponds to nine game combinations.

The following example illustrates the notion of domination. Suppose a duopoly in the goods sector (worth 100 million euro) where firm 1 (E1) is market leader and posts a value of 70%. E1 is confronted by a “challenger” (E2) that is smaller in scale and in full development. Market studies show that a 30 million euro advertising campaign will have a bigger impact on the sales of the challenger than on the sales of E1:

– if E2 goes through with the ad campaign and E1 does not: the respective market shares of the E2 and E1 should reach 40 and 30 million euro;

– if E1 advertises and E2 does not: the respective market shares of E1 and E2 should reach 50 and 20 million euro;

– if E1 and E2 both advertise: E2 should reach a total profit of 15 and E1 of 25 million euro;

– if neither E1 nor E2 use ad campaigns: the respective earnings should be of 70 and 30 million euro.

The payoff matrix is the following:

		Firm 2 Advertize	Don't advertize
Firm 1	Advertize	(25,15)	(50,20)
	Don't advertize	(30,40)	(70,30)

The dominant strategy for E1 is "do not advertise". When E2 adopts the same strategy, E1 will be better off if it does not advertise and maintains its substantial advantage. In the opposite case, E1 still has no incentive to invest in an ad campaign in order to collect 25 million euro whereas it could collect 30 million euro by simply not investing in advertising. From the moment where E2 knows that the dominant strategy for E1 consists of not advertising, it must choose to either align itself and achieve 30 million euro, or go through with an ad campaign and achieve 40 million euro. It should clearly choose the second solution. The outcome of the game is therefore no advertising for E1 and an investment in advertising for E2 and the payoffs will be (30 and 40 million euro) and the market share for E1 is of 30 million euro rather than 70 million euro.

Box 2.1. *Simultaneous decision and dominant strategies (adapted from [GAR 07])*

In sum, an SDS for one player is never played. If a player identifies an SDS, even if he or she does not know exactly what that player will do, he or she does however know what that other player will not do.

The problem then becomes slightly simpler for that player: the SDS is eliminated from the set of possible choices. The latter then reasons in a more limited strategy space than before.

The examples previously presented and the behavioral mechanisms they describe can be integrated into a wider typology of games that present the same properties, often known as the “prisoner’s dilemma” in reference to a founding game. Given that the two players cannot communicate with one another, what should A do? Confess and hope for a lighter prison sentence (3 months). This solution is supposedly better than the one that consists of denying and spending a year in prison. A has an additional reason not to confess. Suppose that A does not confess, while unbeknownst to them, B goes ahead and confesses to the judge. In that case, A will receive 10 years imprisonment. The other player is faced with the same dilemma. In sum, the “do not confess” strategy is strictly dominant for both players A and B.

		Player B	
		Not to confess (NTC)	Confess (C)
Player A	Not to confess (NTC)	(1 year, 1 year)	(10 years, 3 months)
	Confess (C)	(3 months, 10 years)	(5 years, 5 years)

Box 2.2. *The prisoner’s dilemma*

It is now a question of determining the solutions and looking at the resulting equilibriums.

This is the game that has probably opened up the most social applications in a number of fields (social sciences, political sciences, geopolitics, psychology, etc.). Let us now focus on applications for this game in the field of business strategy. The following text boxes present real examples of companies that were confronted with situations of the prisoner’s dilemma in different contexts.

"On the [French] mobile telecoms market, there are three main players that share most of the market. They are Orange, SFR and Bouygues. A fourth one, Free, has presented a ferocious competition from 2012 onwards which should see the prices of subscriptions decrease. There are also a number of alternative mobile companies such as Virgin. In late 2010, French legislation put an end to the active VAT in the mobile telecoms sector. VAT is now at the normal level of 19.6 % as opposed to the previous level of 5.5 %. French law considers that in customer-business relations, the price of a contract is to be negotiated with taxes included. Therefore, if a firm decides to transfer the VAT increase to the customer, this will be a modification to the contract which a customer can then refuse. In that case, despite the 12 or 24 month contractual commitment agreed by the customer, they would have a legal time-frame of a number of months to break that contract.

Analyzed in economic terms, the options for mobile companies are the following, and are oddly similar to the prisoner's dilemma:

If the three main companies decide to not transfer the VAT to the customers, none will lose any customers but they will each lose a substantial profit margin. For the sake of argument, let us say that this loss would be rounded to 240 million euro (60 million telephones, an average contract price of 30 euro, and an increase of VAT from 5.5 to 19.6 %) or a cost of 80 million euro per firm.

If all three companies collaborate and decide to transfer the VAT costs to their customers, they will all give their customers the freedom to break their contracts. Most customers will not use this opportunity, either being out of their commitment period or not wishing to change phone firm. A number (let us say 4% of customers) will use this legal opportunity to change firm and most of them will jump to one of the other two major companies (a minority of them that we will evaluate at 10% or 0.4% of the total will join an alternative MNVO phone firm) in order to get a new phone. This number would also be limited by the fact that the prices of contracts would remain comparable between operators, since they would all increase their prices across the board. It would therefore be a zero-sum game, since new customers would compensate for lost customers. The only costs in that event would be the administrative costs of changing firm, the cost of offered phones and the marginal cost of customers leaving for MNVO companies. For the sake of argument, let us assess this loss to 120 million euro or 40 million euro per firm. Faced with these two choices, the companies would benefit from transferring VAT costs to customers.

The prisoner's dilemma would not be complete if it did not consider a third possibility, which is that one player betrays the others. If one firm decides to not increase the VAT on its contracts, while the others do, the effect of communicating vessels will no longer work and the traitor will significantly increase its subscribers, without losing any customers. For the others, the loss would be significant since not only would they suffer from the costs of new phone offers to arriving customers, but also the loss of millions of customers. Once again, by analogy with the prisoner dilemma, we could assess these costs to 150 million euro, while the loss of margin would be compensated for the traitor by the acquisition of new clients, leading to a loss of 0.

On the first of January 2011, the VAT hike came into effect. The companies must give one month's notice before increasing the prices, so Orange and SFR sent letters to their customers in January informing them that the VAT increase would be affecting their contracts starting February 2011 (thus beginning a legal window for customers to change firm for the 4 months following). As we have seen, the optimal economic solution according to Pareto would be for Bouygues to also increase its prices. However, Bouygues' interests were not necessarily in line with those of the market. Bouygues decided not to increase VAT and took out full centerfold spreads in the paper throughout the entire first week of February 2011 with the message 'Le prix de votre forfait mobile augmente suite à la hausse de la TVA? Alors vous n'êtes plus engagé. Réagissez, ne subissez pas. Rejoignez Bouygues Télécom'[1]. The firm goes so far as to offer legal advice by stating that "la modification de votre offre sans votre accord constitue une modification contractuelle au sens de l'article 121-84 du code de la consommation'[2].

Bouygues Télécom's announcement and its massive campaign led to a massive number of contract breaks from its competitors during the first week of February. Orange and SFR had no choice but to back-track and inform all of their customers on the 5th of February 2011 with the following

1 "Is the price of your subscription rising due to the VAT increase? Then you are no longer held to your contract. React, don't endure. Join Bouygues Télécom".

2 "The modification of your contract without your consent is a contractual modification as described by article 121-84 of the French Code de la Consommation".

text message from SFR: 'Info SFR: VAT, good news, the price of your contract will not be increasing'.

As demonstrated by the prisoner's dilemma, from the absence of collaboration between all three companies, they were all forced to opt for the non-transference of VAT, leading in this case to a loss of 80 million euro per firm, while collaborating would have allowed that to reduce by half. The lack of collaboration also allowed Bouygues Telecom to reduce its losses by acquiring thousands of customers from its competitors. It is therefore probable that in this example, the opportunistic behavior means that losses would have been closer to 100 million for both Orange and SFR and only 40 million for Bouygues. The use of legal resources therefore allowed Bouygues to obtain a competitive advantage towards its competitors".

Source: Olivier Beddeleem (February 2011)
http://legalstrategy.canalblog.com/archives/2011/02/08/20334717.html

Box 2.3. *The increase in VAT for the mobile sector in late 2010 and its repercussions on the phone companies' strategies*

Oil: the prisoner's dilemma

"A global agreement, joining the member states of the OPEC and other producers, would be the only way to sustain the crude oil prices. But a lack of mutual trust means that the conditions for that to happen are far from being fulfilled.

Hope was short lived. Thursday 28th January, crude oil prices jumped following a declaration by the Russian minister for Energy: Alexander Novak just announced that Russia was ready to cooperate with the OPEC (of which it is not member), towards a 'coordination' in the face of the crash of the barrel price. He mentioned a meeting that would take place in February, a proposition by Saudi Arabia to reduce oil productions by 5% for all nations, member or not, of the cartel. People got excited, this was the first time since June 2014 that someone close to Russian power had even discussed the possibility of an agreement with the OPEC.

Such an agreement would be the only way to sustain oil prices. Saudi Arabia, ring-leader of the OPEC, had said it since the beginning of the crisis: the OPEC alone could do nothing, as the price crash (which has suffered by 75% in 18 months!) was first and foremost due to the strong increase in raw supply, linked with the non-conventional boom in American crude oil and decrease in demand as during previous crises. A decrease in production would be immediately compensated by new extractions and a fall in market shares.

Even if certain members of the cartel like Venezuela or Algeria have called for support of the prices, Riyad has always said that it would never be possible without an agreement with non-OPEC nations. Until now, Moscow has always refused. But today, with a barrel price reaching 30 dollars, the pressure on manufacturers' finances has reached critical levels. Even Saudi Arabia is suffering. Offering a barrel for 26 dollars this year, it has presented a 2016 budget in deficit for the third year running despite the numerous internal subsidies.

In all logic, manufacturers' would be far better off sacrificing a (small) part of their production. Francis Perrin, the President of *Politiques et Stratégies Energétiques* tells us 'We would have to withdraw approximately 2 million barrels per day, corresponding to estimated excesses, to rebalance the market and raise prices'. A relatively low volume in comparison with global production (95.7 Mb/j in 2015 according to the US EIA). It is doubtless impossible for a country like the United States, where thousands of small companies officiate, to decree a rationing. It is, however, feasible in most countries where the companies are controlled by the government, as is the case in OPEC-member nations. In the past, Norway, Mexico, Oman and Russia have joined discussions with the cartel to support prices. 'A 5% reduction throughout all these countries would be enough', estimates Francis Perrin. The rebound in price would then compensate for the losses in revenue due to sacrifices in volume. 'It is better to sell a barrel for 50 dollars than two at 30 dollars', admitted a leader of the Russian firm Lukoil.

Since the announcement by Alexander Novak, hope has, however, disappeared – and with it, the price of crude oil. The imminence of a meeting has been denied by the leaders of the OPEC. Saudi Arabia has made no official comment. Most analysts remain skeptical on the likelihood of an agreement. Even Russia barely believes in it anymore: on Wednesday, its representative at the OPEC stated it was 'not likely' that there would be a meeting soon.

The fact of the matter is that there are many inhibitors. First among them, the lack of mutual trust. 'We are confronted with a classic prisoner's dilemma as described in game theory: all players have a collective interest in getting along, but if one actor plays the game alone, he will end up losing', explains Denis Florin, associate at Lavoisier Conseil. In other words, Saudi Arabia, the largest manufacturer of the organization, wants to make sure it won't be the only one reducing its production, so as to not lose market-shares. 'The OPEC is very suspicious of Russia as in the past it hasn't always held its promises', says Francis Perrin. Even within the cartel, there is dissent. 'The level of cooperation between member-countries of the Opec has always been historically tenuous, in particular in situations of market uncertainty', notes Matthieu Auzanneau, author of a reference title around the history of oil and head of prospective at the Shift Project".

Source: Anne Feitz (August 2, 2016)

https://www.lesechos.fr/idees-debats/editos-analyses/021669831976-petrole-le-dilemme-du-prisonnier-1198302.php#tHu69vIkeOtt7Y1w.99

Box 2.4. *Crude oil and the prisoner's dilemma*

The prisoner's dilemma has raised many comments as it leads us to reflect on the relationship between individual and collective rationalities: each of us acts according to his or her own best interest and the result is less satisfying for everyone than it could be. The players can end up collectively resolving to accept inferior gains [SHO 06].

> "The prisoner's dilemma is fascinating as it depicts an interaction between rational individuals which leads to an abhorrent collective result. Each one of us does what is best for him/her, but the result is disappointing to say the least. It is an eloquent illustration of the circumstances under which the lack of coordination leads players to an inefficient result which could certainly be improved". [GON 06]

As we have seen previously, prisoner's dilemma situations are frequent and can concern collective benefits (everyone trying to benefit without having to pay his or her part), quotas destined to prevent a price drop but which are widely disrespected by the actors involved and finally an advertising campaign destined for a matching product or service, the prices of which can be extraordinary, and end up cancelling each other out [GUE 04].

2.2.1.2. *Process of elimination for strictly dominated strategies*

Each time a player detects a strategy (or more than one) that is strictly dominated, he or she eliminates it (or them if there are more than one) from the set of possible choices. The player's reasoning then focuses on a reduced payoff matrix: of one line (or more than one) if he or she is the "line player" who detects the dominated strategy; of a column (or more than one) if it is the "column player" who detects it. This process is known as "iterated elimination of strictly dominated strategies" (IESDS).

2.2.1.2.1. First stage reduced matrix

Suppose that the "line" player (designated by the letter L) has detected an SDS that belongs to his or her space of possible strategies. Suppose also, still to simplify things, that the "column" player (designated by the letter C) has no SDS. Because L has eliminated this SDS of his or her gain matrix, the question is to see whether C is informed of this operation (by, e.g., simply putting himself or herself in the other player's shoes). Suppose that this is the case. C knows that L is now thinking of his or her future strategy within a reduced matrix rather than the original matrix. This decision is rational because C knows perfectly well that his or her opponent will never use an SDS.

Under this information hypothesis (C knows that his or her opponent has eliminated the SDS), both players reason on the same matrix: a reduced matrix. Everything continues as if the game was redefined on the basis of a new gain matrix and the game was to start at that point. The reduced matrix can identify an SDS for C, even if there were none in the initial matrix.

We can show that it does not give L the possibility if there was only one SDS in the initial matrix.

2.2.1.2.2. Second stage reduced matrix

In a second stage, the reduced matrix could very well allow C to find an SDS, which it could not initially. If C finds an SDS (or more than one SDS) in the reduced matrix, he or she eliminates it (them) in turn. The matrix is then further reduced. We are then looking at a second stage reduced matrix. L then integrates this operation *on condition he or she is informed of it* (or anticipates it).

In other words, in order to rapidly identify a (weakly) dominated strategy or an SDS, one can simply put a relatively simple process into place where the elimination criterion is applied at each stage.

All games cannot be solved via a process of elimination of SDS. Still the cases are rarer where such a process leads to a single result after only one round of elimination. In certain cases, a number of rounds of elimination are required and each turn sees a "new game" appear, with one less possible strategy than the previous one and that constitutes the new "workspace" for the players (under the condition of a common knowledge that we will see more in depth later in the book).

2.2.1.2.3. Second stage matrix "workspace" for both players: necessary conditions

For the second stage reduced matrix to serve as a workspace for both players, we need two conditions: first, the row player must know the operation performed by the column player (SDS elimination from the first stage reduced matrix) and, second, the line player must know that the column player knows that he or she (the line player) has taken into consideration the process of SDS elimination, and that the column player knows that the line plays, etc. and so forth.

This "condition of psychological convergence" guarantees both players that the second stage reduced matrix is indeed the matrix they are both looking at as representing their possible strategies and outcomes of the game, as is explained by [THI 00]:

> "The process of elimination (or process of successive dominance) requires more sophisticated behavior that lends itself to the prisoner's dilemma game, insofar as each player must be able to reconstruct operations in regards to how the other player proceeds and deduce from the operations the implications that arise".

2.2.1.3. *Process of elimination of weakly dominated strategies*

The elimination of SDS simplifies the game by reducing the space of available strategies to players. It does not, however, always allow players to solve the game because they can get stuck on one of the levels of the process (even the first one if there is no SDS in the initial matrix) and the process stops (it does not converge toward a final outcome). There are a certain number of games for which the process of elimination of SDS yields no "solution". Although it is easy to state that any rational player would abandon an SDS, it is harder to adopt the same argument as for weakly dominated strategies.

Another difficulty resides in the presence of multiple solutions [RAS 04] in the frame of an iterated elimination of strictly dominated strategies as opposed to a solution via IESDS which, if it exists is unique. A solution obtained via weak iterated dominance is not necessarily unique because the order through which the strategies are eliminated can influence the final solution. The result is therefore dependent on the order in which the eliminations are made (see Box 2.5).

	C1	**C2**	**C3**
R1	**3,13**	2,11	**2,13**
R2	1,13	1,11	1,12
R3	1,13	2,11	1,14

The combinations of strategies (R1, C1) and (R1, C3) are both equilibriums of iterated dominance, because each one can be generated via iterated deletion. A possible order of deletion is (R2, C2, C1, R3), which leaves (R1, C3). W first eliminates R2 because that line is dominated by R1 and then C2 because that line is dominated by C3. It then remains the following game:

	C1	C3
R1	3,13	**2,13**
R3	1,13	1,14

In this game, C1 is dominated by C3 and therefore the action C1 is eliminated. Similarly, R3 is deleted because it is dominated by R1. All that then remains is (R1, C3). However, if the deletion progressed along (R3, C3, C2, R2), it would leave (R1, C3) when the game is reduced to a North-West corner. In addition, if the dominated strategies were simultaneously deleted at each stage, R3, R2 and C2 would be eliminated as soon as the first stage, which would leave (R1, C1) and (R1, C3), and no other additional iteration would be possible.

Box 2.5. *The "iteration path" game (adapted from [RAS 04])*

2.2.1.4. *What are the lessons learned from a management perspective?*

The various games and concepts presented above seem too far removed from the decision-making processes in companies. This is not the case. These first lessons can have very concrete implications in the lifespan of a firm:

– in a general sense, managers have a margin of maneuverability higher than they may imagine. This is due to the information at the disposal of a firm on the evolution of the "strategic space" of its competition (an eventual decrease of this via the example of the existence of SDS in its competitor's space), which would allow it to exclude strategies from its set of choices and to focus on a more restricted set of possible strategies. This approach would lead to a simplification of its own strategic space;

– a strategy is not "good" or "bad" in and of itself unless it is a strictly dominant strategy, in which case it will be systematically adopted;

– the evaluation of a strategy must always be performed in anticipation of the competitor's action, a decision based on the hypotheses made about the state of mind of one's opponent: a manager can, for example, lose "the battle" because it is falsely supposed that a rival firm would adopt a rational behavior, which ended up not being the case. In other words, a rational player can lose against an irrational player.

2.2.2. *Maximin and Minimax solutions or the search for a new level of security*

The concepts of solution based, in particular, on the process of elimination of dominated strategies are not always applicable. What approach can we use to give more predictive power to the theory? We must then reference other reasonings of the type "Maximin" and "Minimax"[3].

2.2.2.1. *Zero-sum games: Maximin and Minimax solutions*

In the context of zero-sum games (with two players: one wins, the other loses), the Minimax rule can be introduced: when player 1 reduces the payment of player 2, it increases his or her own.

Punishing the other player equates to rewarding oneself. The solution formed by Minimax strategies corresponds to the case where gains of the players are equal to their level of security.

The following matrix allows us to deduce the following results: player A chooses the second line A2 where he or she obtains a minimal gain of 2 (9 is higher than –4 and 2 is higher than –8). Player B chooses B2 by following the same reasoning independently of player A's rationality or lack thereof.

		Player B	
		B1	B2
	A1	(-4, 4)	(-8,8)
Player A	A2	(9, -9)	(2, -2)

This game leads to a *stable* equilibrium {A2, B2; (2; –2)} and is deterministic. In this type of game, A and B will always choose a strategy that will correspond to an equilibrium point or even a saddle point if they are rational.

Maximin aims to maximize a player's minimum possible gain, whereas the Minimax aims to minimize a player's maximum loss[4].

3 These notions, and more specifically "the Minimax theorem", were developed by Von Neumann (1928). This theorem constitutes not only one of the most important theorems of game theory, but it was also generalized to applications in other mathematical fields (see Appendix 1).

4 The difference between the two is not obvious. Indeed, because the "Minimax" strategy refers to the fact that a player chooses the strategy that minimizes the greatest possible gain for an opponent and maximizes his or her own [SHU 82b] and the "Maximin" behavior can also be considered to minimize the maximum loss that could be inflicted [RAS 04], decision theorists qualify this rule and the Minimax criterion [LUC 57].

These "defensive" strategies help limit the effects on their payments short of predicting the best strategies of players. They are linked to discussions surrounding the degree of severity of punitive measures as they lead to more severe sanctions. They can either be pure strategies or mixed strategies.

Let us look again at the prisoner's dilemma we mentioned previously. In this game, the Minimax and Maximin strategies both involve confessing. In a Maximin strategy, player 1 has the first move and therefore believes that player 2 is unable to be treacherous. In a Minimax strategy, player 2 wants to eliminate his or her "rival" but for that he or she must play first if he or she wants to fully exert his or her "disruptive power" over player 1.

These Minimax and Maximin strategies have given rise to numerous interpretations on the behavior of players. Therefore, [RAS 04] considers that in zero-sum games, players are "simply neurotic": Minimax is for "optimists" and Maximin is for "pessimists". In variable-sum games, Minimax is designed for "sadists" and Maximin for "paranoid players".

> Decisions are often made in situations of uncertainty as we already mentioned in Chapter 1. As [MAN 96] reminds us, "we speak about uncertainty when, in a given situation, probabilities cannot be calculated. Risk exists when the result is not certain, and when the probability of each possible result is known or can be assessed. Uncertainty arises in a situation when probabilities are unknown. A number of rules have been developed to assist decision makers in making choices from possible attitudes in uncertain conditions, but none are considered to be preferable to others".
>
> This is the case of the Maximin rule that is problematic for acting in situations of uncertainty: the decision maker must determine the worst possible outcome for each type of action and choose the one that has the most desirable worst outcome for his or her firm.

Box 2.6. *The Maximin rule: what are the lessons learned from a decision-making perspective? (adapted from [MAN 96])*

2.2.2.2. *Generalization: the cautious strategy*

Caution is considered to be the state of mind of a player that shows "restraint" in a situation of *n* strategic interaction. A cautious player first looks to identify the worst situations of his or her opponent and the strategies that lead him or her there. He or she then selects the best situation among the ones that have been identified. In our example, the "best of the worst" for E1 is to obtain 3 by playing strategy A: 3 is therefore called the maximum gain for E1.

The following matrix illustrates this notion of caution strategy. Suppose the following gain matrix summarizes the confrontation of two companies E1 and E2:

Cautious strategy for E1: (A)

Cautious strategy for E2: (A)

		E2			Min line
		A	B	C	
A	A	(4,2)	(9,1)	(3,7)	3
E1	B	(5,4)	(2,3)	(4,0)	2
	C	(1,3)	(4,2)	(5,2)	1
	Min column	2	1	0	

Outcome (A, A) is a cautious strategy. It is the outcome of the game if both players adopt a cautious strategy. However, the applications of the Minimax theorem are limited in the sense that the targeted games are all zero-sum. This is why other solution concepts were researched. This is the case for the concept of Nash equilibrium that is defined for non-descript games (zero-sum and non-zero-sum games). Nash equilibrium is presented in Appendix 2.

2.3. Process of dynamic decisions: solutions concepts

Repeated games are often referred to as "dynamic games", an expression that does not satisfy everyone in the theorist community. Some are opposed to it, highlighting the fact that repeated games lead to exclusively static solutions. On a terminological level, [GUE 96] considered that the main difference between repeated games and sequential games is that repeated games indefinitely reveal new and numerous solutions as opposed to normal sequential games [GUE 96]. In practice, a number of studies on game theory use one or the other of these terminologies depending on the context: sequential games for contexts where players operate per period or a different set of players every period (states in one period, companies in another, etc.), repeated games for contexts where a *same* stage game (generally static, associating a number of players) is repeated through time.

Works on repeated games are numerous and their resolutions can sometimes require technical artifacts, which we will avoid in this section. We discuss games that help us analyze more thoroughly the notions of negotiation, bribing and threatening.

2.3.1. *"Non-cooperative collusion" or "tacit collusion"*

This presumably contradictory term refers to the possibility for a firm to be colluding with another without there ever being an explicit agreement between the two [VIC 85]. Player behavior in a non-cooperative environment depends on the state of information of players, the importance each player grants in the future to his or her calculations and the number (finite or infinite) of games[5] played for each game. Many authors [AXE 84, DIX 82, DIX 99, FRI 71, ABR 86, SEG 88] have highlighted strategies that lead to adopting (or even maintaining) non-cooperative collusive balances.

2.3.1.1. *Tit-for-Tat strategy*

Axelrod [AXE 84] attempts to answer the following question: "under what conditions will cooperation emerge in a world of egoists without central authority?" For this, Axelrod [AXE 80a, AXE 80b, AXE 81, AXE 84] developed the concept of "Tit-for-Tat", meaning the player cooperates during the first stage, but then afterward chooses the strategy adopted by his or her opponent at the previous round.

5 For each of the games presented, we will specify the number of games played.

2.3.1.1.1. The single period model

[AXE 84] uses as a starting point in his model his demonstration of the prisoner's dilemma, that is, let us restate, a two-player game in which each can cooperate (C) or defect (D). If they both cooperate, they obtain the reward R (see the following matrix). If they both defect, they both get the punishment P. If one cooperates and one defects, the former obtains S (S = suffers the other player's defection, sucker's payoff) and the other gets T (T = attempt to usurp the other player).

		Player 2	
		Cooperate	Do not cooperate
Player 1	Cooperate	(R=3, R=3)	(S=0, T=5)
	Do not cooperate	(T=5, S=0)	(P=1, P=1)

Table 2.1. *A numerical example of the prisoner's dilemma (adapted from [AXE 80a, AXE 80b, AXE 81])*

The gains can be categorized as follows: T > R > P > S and satisfy R > (T + S)/2. In the sense that the players cannot communicate among themselves (hypothesis of the model), each player has an incentive to not cooperate independently of the choice performed by the other player. Each player's strategy will be to adopt a non-cooperative behavior, which results in a lower gain than the one he or she would have obtained in the case of mutual cooperation. As was mentioned in the previous chapter, this solution is not optimal according to Pareto.

2.3.1.1.2. Finite number of games

Consider a repeated game with a finite horizon. In such a case, it is theoretically the non-collusive solution that is likely to take it (see the exception in Box 2.7). During the final stage, each player will have incentive to play "non-collusively", since beyond this point, the game is over and there are no possible repercussions. At this point, at the previous stage, with each firm knowing that the other player will no matter what be non-collusive in the last stage, each player will use a non-collusive policy at the second to last stage. Cooperation is difficult to imagine unless the information hypothesis is lifted.

Furthermore, the emergence of cooperative behavior depends on the value of the level of actualization w ($0 < w < 1$), meaning the value that the players grant to the future payments, which subsequently conditions the choice the players make during the previous period. This actualization factor w is also interpreted as being the probability that the game will continue in the following period. If this probability is sufficiently high, an equilibrium, corresponding to collusive non-cooperative behaviors, will once again be met [JAC 87].

Example: stage game with multiple equilibriums and sustainability of cooperation

Certain games present characteristics that sustain cooperation even when the game is repeated a finite number of times. The cooperation can indeed be sustained by the players using the threat of retaliation they can make and promise to execute if a cooperative behavior is not observed during early stages of the game. The following matrix presents a characteristic that is favorable to the appearance of cooperation.

		Player 2 (P2)		
		D	E	F
Player 1 (P1)	A	(1, 1)	(5, 0)	(0, 0)
	B	(0, 5)	(4, 4)	(0, 0)
	C	(0, 0)	(0,0)	(3, 3)

The matrix admits two Nash equilibriums in the stages game: (A, D) and (C, F).

The Nash equilibrium (C, F) strictly dominates the Nash equilibrium (A, D). The Pareto outcome (B, E) strictly dominates the two Nash equilibriums.

Suppose now that this game is repeated twice. At the second period, one of these two Nash equilibriums (A, D) and (C, F) will be able to emerge. The two players look to collectively realize the most satisfactory outcome (B, E) at least at the first stage of the game. To realize the outcome (B, E) at least for this stage, both players must use the threat of the following retaliations:

– strategy announced by player 1 (noted δ1): play B at the first stage then C at the second stage if (B, E) was observed in the first, and A if not;
– strategy announced by player 2 (noted δ2): play E at the first stage then play F at the second stage if (B, E) was observed at the first, and D if not.

If P1 remains true to the announced strategy, we verify that player 2 does not have incentive not to cooperate at the first stage. Indeed:

– if P2 does not cooperate, he or she gains 5 at the first stage and 1 at the second stage for a total gain of 6;
– if P2 cooperates, he or she gains 4 at the first stage and 3 at the second stage for a total of 7. P2 therefore cooperates, as this will increase his or her gains.

The game being symmetrical, we obtain a similar result for player 1. Cooperation can be sustained: each player just needs to threaten to play the "worst" of Nash equilibriums of the stage game (the one that is strictly Pareto dominated) at the last stage.

Box 2.7. *Sustainability of cooperation in a finite repeated game*

Situations of competition do not always have characteristics that are favorable to the emergence of cooperation in a game that is repeated a finite number of times (see the following matrix). Take for example a commercial strategy policy of two companies[6] (E1 and E1) whose action variable is price declined into three levels: p1 (high price), p2 (competitive price) and p3 (promotional price). The following gains matrix (matrix at the first stage) represents (3 × 3) possible situations depending on whether each firm adopts one of the three announced prices.

6 This expression is commonly used to refer to the measures that can be used to develop the balance generated by the situation of a market, to the benefit of a protectionist State. This expression is used here to describe the price policy adopted by a firm rather than in a context of international economics.

		Firm 2 (F2)		
		p1	p2	p3
	p1	(10, 10)	(6, 14)	(0, 20)
Firm 1 (F1)	p2	(14, 6)	(8, 8)	(6, 7)
	p3	(20, 0)	(7,6)	(-5, -5)

The Nash equilibrium is (p2, p2). The game is repeated twice and companies put in place their threat/promise strategies:

$\delta 1 = [p1, (p2/(p1,p1), \text{if not } p3)]$

$\delta 2 = [p1, (p2/(p1,p1), \text{if not } p3)]$

If we take into account these threats/ promises, the game is entirely determined within the first stage of the game. The choice of the first stage mechanically determines (if these threats/promises are executed) the outcome of the second stage. The problem with such threats is that if cooperation does not occur in the first stage, it is not in the interest of either player to execute threats; the only rational outcome that will prevail is the Nash equilibrium (p2, p2). This difficulty is tied to the question of threats (see further on).

2.3.1.1.3. The appearance of cooperation in an infinitely repeated game

In this model, the game of the prisoner's dilemma is repeated an indefinite number of times. Thus, no player can predict which will be the final game. In these conditions, the players are aware that a defection on their behalf will lead to retaliation from their "partner" under the form of a defection throughout the following game (or the following game). Each player is therefore aware of the attitude he or she adopts at a period *t* and will have repercussions not only on the gains for that period, but also on the gains that will follow. The value of *w* will therefore play a fundamental role in this infinite horizon game. The closer it is to 0, the less the players attach an importance to the future and adopt a short-term strategy. On the condition that companies grant a certain importance to the future, meaning if *w* is high enough, meaning close to 1, it is possible for one non-cooperative collusion to occur.

According to [AXE 84], players think the future is less important than the present (thus w[7] is lower than 1) and this is for two reasons: "The first is that players tend to value payoffs less as the time of their obtainment recedes into the future. The second is that there is always some chance that the players will not meet again. An ongoing relationship may end when one or the other player moves away, changes jobs, dies, or goes bankrupt". This is why the payoff for the second game always has less value than the one currently ongoing. To account for this, we can cumulate the results through time in such a way that the next "move" will be worth a fraction of the current move. The weight of the next "move" in relation to the ongoing one is called w. This parameter w can be used to determine the payoff of an entire series of moves. [AXE 84] uses the following example: he supposes that each "move" is worth half of the previous "move", that is $w = ½$. Therefore, a series of mutual defections worth one point each will have a value of 1 at the first move, ½ at the second, ¼ at the third, etc. The cumulative value of this series would therefore be of $1 + ½ + ¼ + 1/8 + \ldots$, which gives us a limit value of 2. By generalizing, if we obtain a point at each go, that is worth $1 + w + w^2 \ldots$. the result that is useful to have for the rest of the demonstration is that the sum of this infinite series for any $0 < w < 1$ is simply equal to $1/(1 – w)$.

The payoff attributed by [AXE 84] in the context of a mutual defection to one of the two players is $P/(1 – w)$. The payment received by a player who does not cooperate against a player using the Tit-for-Tat strategy is $T + wP/(1 – w)$. He or she obtains T in the first game, then P. Finally, the received payment by each of the players in case of mutual cooperation, that is, in case of the application of a Tit-for-Tat strategy, is: $R + wR + w^2R \ldots = R/(1 – w)$.

If the actualization factor is sufficiently high, there is no better strategy that is independent of the opponent's. Suppose the other player had to adopt the systematic "lone rider" strategy. If the other player never cooperates, it is in your best interest to also use a lone rider technique. However, in the case where the other player performs "permanent retaliations", meaning he or she adopts a strategy

7 Axelrod has named "w" the discount parameter.

consisting of cooperating until you go lone rider, then always going lone rider, your best strategy is to never go lone rider. This is valid on the condition that the temptation to go lone rider on the first turn is more than compensated by the inconvenience of not getting anything other than punishment P rather than reward R on the following moves. This will be the case each time w is high enough. Thus, the choice to cooperate or not, even the first time, depends on the strategy adopted by the other player. So if w is sufficiently high, there will be no absolute strategy.

Axelrod continues his demonstration by affirming the proposition according to which Tit-for-Tat is a collectively stable strategy if it resists[8] a defection strategy and a strategy alternating cooperative and non-cooperative behaviors. This proposition is verified by the following condition (S being the sucker's payment):

$$w \geq (T - R)/(T - P) \quad \text{and} \quad w \geq (T - R)/(R - S)$$

Saying that a Tit-for-Tat strategy of cooperation (C) resists a defection strategy (D) means that the value (or score) referred to by V of strategy D in its interaction with strategy C is, say:

$$V(D,C) \leq V(C,C)$$

As we have seen previously, $V(D,C) = T + wP/(1 - w)$. Since one player always cooperates with his or her counterpart: $V(C, C) = R + wR + w^2R \ldots = R/(1 - w)$. Then, the defection strategy cannot "overwhelm" the Tit-for-Tat strategy when:

– $T + wP/(1 - w) \leq R/(1 - w)$;

– or $T(1 - w) + wP \leq R$;

– or $T - R \leq w(T - P)$;

– or $w \geq (T - R)/(T - P)$.

8 In this context, the term "resist" means that the adoption of the strategy yields a superior gain to the ones that would have resulted from the other strategies.

Similarly, saying that the Tit-for-Tat strategy resists a strategy alternating defection and cooperation means that:

$$(T + wS) /(1 - w^2) < R /(1 - w) \text{ or } (T - R)/(R - S) \leq w$$

Therefore, $w \geq (T - R)/(T - P)$ and $w \geq (T - R)/(R - S)$ are the same as stating that the Tit-for-Tat strategy resists equally well to both a systematic defection strategy and a strategy alternating defection and cooperation.

Axelrod continues his demonstration stating that as "Tit for Tat" can withstand both aforementioned strategies, it can withstand any other strategy. He then concludes that Tit-for-Tat is a collectively stable strategy.

2.3.1.2. *The Trigger strategy*

The Tit-for-Tat strategy is not the only strategy that allows a player to maintain a non-cooperative collusive profit. The other strategy is the "Trigger" strategy[9]. The model we are referencing describes this strategy to be that of Friedman [FRI 71]. Each player adopts a collusive strategy as long as the competitors also implement a similar strategy in all previous periods and use a non-cooperative policy during all periods that follow the one where one of the players should choose to play "free rider".

[FRI 71] considers that each firm uses a collusive price pm as long as its competitors will do the same thing in previous periods and adopt a non-cooperative price pc in all periods that follow the one where one of their competitors chooses to practice a price below pm. Each player is supposed to maximize the sum of his or her profits.

Tacit collusion is reinforced if many conditions are gathered. First of all, short-term profit coming from defection must not be infinite and there must also be a reasonable sanction in case of a defection [JAC 87]. This collusion is non-cooperative because companies do not

9 [MAR 93] associates this strategy to the following expression: "the grim reaper".

act in concert, each one acts as best it can independently, the strategy adopted by the other firm is given.

The result of the Trigger strategy allows players to obtain higher gains than those that would yield from a Cournot equilibrium. This constitutes an example of the folk theorem that comes from a unanimous observation by game theorists: going from a repeated game with a finite horizon to game with an infinite horizon has repercussions on all equilibriums. This theorem can be formulated as follows: any individually rational solution that gives players a superior gain to their minimum guaranteed, that is to their level of security, can be obtained by a Nash equilibrium in an indefinitely repeated game. If a player deviates, the others punish. In that case, the average payoff will be lower than the rational individual payment. It is therefore possible to obtain mutual cooperation in the prisoner's dilemma because no player has any incentive to deviate. It is therefore a Nash equilibrium, as stated by [GUE 93]:

> "The demonstration of the folk theorem is based around threat; the strategy involves choosing every action with an outcome that is the same for all players, and sanctioning any deviation from the norm. It is an equilibrium strategy, if it is employed by the players […]. The method used when faced with multiple Nash equilibriums involves searching for "refinement". Among these equilibriums, there are perfect ones, whose threat credibility is taken into account. However, the threats involved in the demonstration of the folk theorem are not necessarily credible, especially since the implementation of such a sanction can be costly (loss of earnings) for the person involved […]. Nevertheless, the folk theorem remains valuable, for the most part, even if one restricts oneself to achieving perfect equilibrium".

To illustrate the Trigger strategy, take the example of offsetting production quotas. If there is only one period in the game, coordination is impossible due to the prisoner's dilemma because the best response to low production is a higher production. Imagine then that the game is repeated three times (over 3 days): the two companies agree the first day and reach a Nash equilibrium; on the second day they anticipate the results from the third day and apply the Nash equilibrium, but as there is no longer any continuity to the game, one of them will betray the other on the third day. We can therefore conclude that coordination is not possible. At all points, there is a Nash equilibrium because the two players are aware that the game has an end. For the coordination to function, the game must be infinite. The players "discipline" themselves when there is a sanction the next day. In other words, the players must not know that the game is based on a finite number of games. As was mentioned earlier, the outcomes are different in the case of a number of infinite periods. As soon as a firm does not affect a probability 1 (certain event) at the end of its exercise on the market, it functions as if the game had an infinite horizon: the likelihood of playing the next period is never null, the firm considers that the number of its interventions is infinite.

Tit-for-Tat	*Trigger strategy*
- cooperation in the case where the other player cooperates with the previous periods - betrayal in the case where the other player betrays the previous period	Cooperation until the other player betrays In case of deviation, the players behave non-cooperatively the remainder of the game.
Tit-for-Tat	*Trigger strategy*
- more indulgent - forgets easily - proportional - credible but lacks in dissuasion	- less indulgent - doesn't forget - "extreme" - adequate dissuasion but lacks credibility
"Is cooperation easy?"	"Is cooperation possible?"

Box 2.8. *Comparisons of the Tit-for-Tat and Trigger strategies (adapted from [SHO 06])*

As we have already highlighted previously, the efficiency of the Trigger strategy for sustaining cooperation in a repeated game is not always guaranteed. It is subordinate to another characteristic: the more or less substantial monetary depreciation (w) through time or preference for the present. The importance of an actualized value of future revenue weighs crucially on the efficiency of retaliation that we are promised in a more or less distant horizon (other than the moment where we deviate). Formally, we can determine the conditions of sustainability of cooperation by taking the following. Suppose that two firms wish to implement cooperation in an indefinitely repeated game. Cooperation consists of the Pareto-optimal outcome that we refer to as (P, P) in reference to the prisoner dilemma. The alternative to cooperation is the Nash outcome (A, A).

The Trigger strategy sustains cooperation (P, P) at all stages of the indefinitely repeated game under certain conditions that surrounds the discount rate *w*. We must demonstrate that if one of the two players is certain that the other will execute vengeance, he or she has every incentive to respect the agreement and play P on all periods of the game. Suppose that player 1 evaluates the benefit of not cooperating. P1 compares the profit made in both of the following scenarios:

First scenario: he or she cooperates (player P) in the first episodes and betrays at period T (by playing A).

Second scenario: he or she cooperates at all periods of the game.

In the following Π^c is the profit from a period obtained by player 1 when the two players cooperate, Π^d the profit they obtain by deviating unilaterally at period T and Π^N the profit of the Nash equilibrium, considered here as the sanction that follows the deviation of the period T.

The updated profit obtained by player 1 in the second scenario is written as:

$$\Pi^c = \sum_{t=0}^{\infty} w^t \Pi^c$$

The updated profit obtained by player 1 in the first scenario (deviation at t = T) can be written as:

$$\Pi^d = \sum_{t=0}^{T-1} w^t \Pi^c + w^T \Pi^d + \sum_{t=T+1}^{\infty} w^t \Pi^N \quad \Pi^c - \Pi^d = \sum_{t=T}^{\infty 1} w^t \Pi^c - w^T \Pi^d - \sum_{t=T+1}^{\infty} w^t \Pi^N$$

Yet: $1 + w + w^2 + w^3 + \ldots + w^T = \frac{w^T}{1 - w^{T+1}}$ (sum of the terms of a geometric series *w*)

$$\lim_{t \to \infty} \frac{w^T}{1-w^{T+1}} = \frac{1}{1-w} \qquad (0 < w < 1)$$

$$\Pi^c - \Pi^d = \frac{w^T \Pi^c}{1-w} - w^T \Pi^d - \frac{w^{T+1} \Pi^N}{1-w} = w^T [\ldots]$$

$$\Leftrightarrow \frac{\Pi^c}{1-w} - \Pi^d - \frac{w\ \Pi^N}{1-w} > 0$$

$$\Leftrightarrow (1-w)\,\Pi^d < \Pi^c - w\,\Pi^N$$

$$\Leftrightarrow w > \frac{\Pi^d - \Pi^c}{\Pi^d - \Pi^N}$$

$\dfrac{\Pi^d - \Pi^c}{\Pi^d - \Pi^N}$ is the discount level from which deviation is non-feasible.

The players respect the agreement if the discount level is sufficiently high, close to 1: the future repression weighs in the decision to "betray the agreement".

Box 2.9. *Trigger strategy and sustainability of an indefinitely repeated game*

2.3.2. *Sequential games*

When the game is sequential in nature, there is no uncertainty linked with the simultaneousness of the choices made by players, we say that there is perfect information (on top of complete information). Before making a decision, each player takes into account the actions taken by other players who have preceded them in the "order of turns". Any decision is therefore "conditional" on the other ones [GUE 93]. The players act in a predetermined sequence in sequential games, which takes the form of a sequence of successive moves.

2.3.2.1. *Perfect equilibrium*

In a situation where there is complete and perfect information, the representation that is still the most adapted is that of the "tree". It is associated with the "reasoning with recurrence", mentioned earlier, which consists of decomposing the game into sub-games, and resolving the sub-games from the end of the game-tree, until the resolution of a game with no sub-game. This method leads to a perfect equilibrium of sub-games, a concept developed by Selten [SEL 75], represented in Figure 2.1. To determine its optimal action (a1 or a2), player A anticipates the reactions of other players to each of his or her actions. He or she puts himself or herself in player B's position who puts himself or herself in player C's position. Through this process, for each of these actions (a1 or a2), player A knows what gain he or she can obtain. He or she chooses the action that provides him or her with the highest gain. Once again, we use the process of resolution via "backward induction". The trajectory [a2, b3, c1] is an equilibrium trajectory. It is a perfect equilibrium of a sequential game.

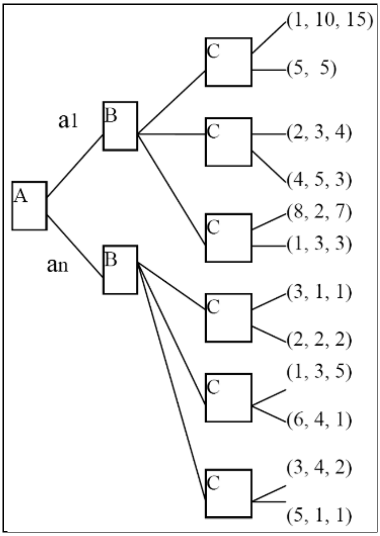


Figure 2.1. *The representation of a perfect equilibrium in perfect sub-games*

In Figure 2.2, the equilibrium trajectory or perfect equilibrium is [b, b].

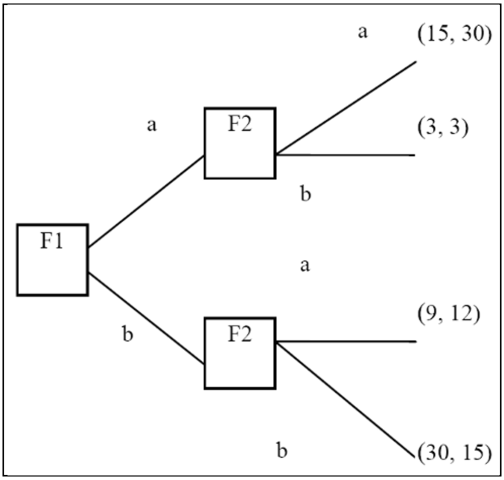


Figure 2.2. *Perfect equilibrium in sub-games: an illustration*

The primary lessons on the perfect equilibriums in sub-games can be summarized as follows:

The criterion for perfection in sub-games developed by [SEL 75] remains the Nash equilibriums, which are often also Nash equilibriums in sub-games. It is easier to find perfect equilibriums in sub-games of a game than all of its Nash equilibriums in all sub-games: perfect equilibriums in sub-games constitute a sub-set of Nash equilibriums (any sub-game equilibrium is a Nash equilibrium), so there are often less to identify.

The criterion for *sub-game perfection* is an example of *equilibrium refinement.* The Nash approach does not generally generate just one equilibrium. In order to explain or predict the behaviors of players in a strategic situation, we need to be able to predict the behavior of players in a strategic situation and we need to be able to discriminate among these equilibriums. Following Nash's work, one of the great fields of research in game theory has involved developing solution concepts that help to more finely discriminate the strategic profiles than the Nash equilibriums. Generally, the retained profits by these new concepts are also Nash equilibriums, in such a way that we talk of *refinement* of the Nash equilibriums. The most used refinement remains the perfect Nash equilibriums in sub-games developed by [SEL 75]. This concept rests on the notion of *sub-games* obtained from the extensive form. A finite game still possesses at least a sub-game Nash equilibrium. There lies the consequence of the Nash theorem. If the game is finite, then all sub-games are also. Consider the final sub-games (those that do not include sub-games). Since these games are finite, they possess at least one Nash equilibrium. Replace these sub-games with terminal nodes to which are associated sequential values for each player to pursue the game with that starting point. Consider now the sub-games that surround these sub-games (which have been substituted for terminal nodes). It is once again a case of finite games that have at least one Nash equilibrium. By doing this, we will have constructed a profile of strategies with one of its characteristics being that it is perfect in sub-games.

2.3.2.1.1. Negotiation and "power sharing"

Sequential games help describe certain situations in particular negotiation contexts (or bargaining) and offer solution concepts. In this type of game, the players are led to cooperate in the case where it will yield them superior gains than if they stayed alone. However, this gain is conditioned by profit sharing, which must be discussed beforehand. The distribution they agree upon is then the outcome of that negotiation procedure.

The problem with "Rubinstein bargaining"[10] is linked to two individuals (or groups of individuals) sharing a cake using a negotiation process. The "cake" in the economic sense can be more of a "pot", a return, a bonus. The individuals take turns proposing sharing methods. Either the opposing party accepts and the game ends, or it does not and the game continues and they suggest a different distribution, etc. The duration of the negotiation is determined in advance: in case they do not agree, a "dictatorial" split is set by a third party authority and imposed on both parties. The "dictatorial" split is

10 Rubinstein, in his founding article in 1982, proposed sequential bargaining models, a sequential procedure that allowed Nash in 1950 to reach the bargaining solution.

known beforehand by both parties. The following box presents Rubinstein's bargaining.

Consider two players P1 and P2 who must share a cake that has a value of 1. The following game represents the negotiation procedure (DEM):

First stage:

– P1 proposes the following divide (x_1, 1 – x_1) with 0 < x_1 < 1.

– If P2 accepts, the cake is shared and the game ends.

– If P2 refuses, the game continues to stage 2.

Second stage:

– P2 proposes the following divide (x_2, 1 – x_2) with 0 < x_2 < 1.

– If P1 accepts, the cake is shared and the game ends.

– If P1 refuses, the game continues to stage 3.

Third stage:

A dictatorial divide is imposed upon players: split (x, 1 – x) known beforehand before the game.

Let us hypothesize that there is a monetary depreciation (or a preference for instant consumption). We suppose that a quantity of x consumed tomorrow is worth w.x today with 0 < w < 1. Using the backward induction method:

Third stage:

– If P1 accepts, he or she wins x_2; if P1 refuses, he or she wins w x.

– If $x_2 < w$ x, P1 refuses; if $x_2 > w$ x, P1 accepts.

Second stage:

P2 observes (x_1, 1 – x_1)

– If P2 accepts, he or she wins 1 – x_1.

– If P2 refuses, there are two possibilities:

- If P2 proposes x_2 such that $x_2 \geq w$ x (finally $x_2 = w$ x), he or she wins 1 – x_2 directly as P1 accepted.

- If P2 proposes $x_2 < w$ x, then P1 refuses and P2 wins w (1 – x).

Yet: $1 - w\,x > w\,(1 - x)$

and: $1 - x_1 = 1 - w\,x \Leftrightarrow x_1 = w\,x$ (P2 accepts).

First stage:

P1 knows the following:

– If $x_1 = w\,x$, P2 will accept and P1 wins $x_1 = w\,x$.

– If $x_1 > w\,x$, P2 will accept and propose $x_2 = w\,x$ and P1 accepts. P1 then wins $w\,(w\,x)$.

Or: $w\,(w\,x) < w\,x$: P1 proposes $x_1 = w\,x$ and P2 accepts.

Box 2.10. *Bilateral Rubinstein negotiation and bargaining*

2.3.2.1.2. Threats and promises in a sequential game

The threats and promises play a key role in sequential games. In the example of the bank robbery (see Figure 2.3), we suppose that in reality b1 < b2, b2 < b4 and a4 > a2. The threat of detonating a grenade is not credible because it is not the best reaction to the banker's refusal. The banker therefore imposes *fait accompli* (refusal) to the robber who at the end cannot detonate the grenade because that action is not his or her best response. An equilibrium trajectory does not include this non-credible threat. Another variant of the game is when we have b3 > b4, b1 < b2, a1< a2 and a3 < a4. The equilibrium in this game will be [give, don't kill].

Two lessons should be learned: first, any credible threat is never executed because its function is to avoid the opponent engaging in an action that leads to the execution of this threat, and second, a non-credible threat can never be on the equilibrium trajectory.

Consider the question of entry on a market. In certain market models, the group of companies already in place can be assimilated into one individual player and this is the case in the context of barrier-to-entry theories. Settled firms are indeed considered either as one single firm or as a "perfect" cartel and therefore monopolistic. In that sense, the model allows for two players: one established firm and another attempting to enter the market. We suppose that the firm (or group leader including *n* companies) uses an irreversible fixed expenses policy that acts as a deterrent toward newcomers. These expenses can include advertising costs, R&D or any other capital expenses.

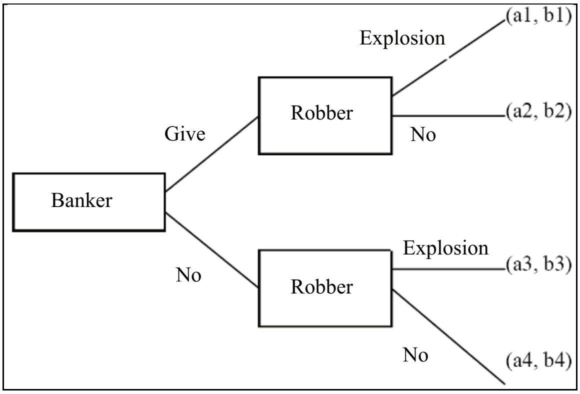


Figure 2.3. *Threat*

In the exposed model, the strategic variable that players have surrounded is R&D. It is a "model of strategic competition" along the terms of [JAC 85], meaning it "relies on the hypothesis of an initial asymmetry. In situations where it is beneficial to have the first move (where there is a struggle for the first move) and where information is perfect, settled companies are favored by an asymmetry before entry: they supposedly have the first move and are capable of making prior and irrevocable arrangements corresponding to credible threats".

Indeed, this model shows how a firm in place can utilize a temporal advantage, which corresponds to the fact that it can accumulate enough capital before the arrival of new companies to create barriers to entry [TIR 85].

This is an analysis we find with many authors. The "strategic advantage" implicitly considered by Bain [BAI 59] is the one that is certainly held by settled companies, meaning the first ones to engage: it is the same type of advantage as the one that Stigler [STI 50] refers to, meaning an advantage that is inherently time-related.

It appears that there can be no other strategic advantage than the one that implies that other involved companies would not have access to the same function of cost, in accordance with Stigler's intuition, and that this asymmetry is essentially a temporal asymmetry where we once again encounter the prominent role of irrecoverable costs that can be fixed but also variable, associated to physical assets or associated with disembodied assets such as customer retention [GAF 90].

2.3.2.1.3. The different equilibriums

In a deterministic context, consider the case of two companies with a finite horizon. One is on the market, the other attempts to enter. Consider the following two situations:

– the first situation where only one "innocent" behavior is permitted, in the sense that the established firm is not attempting to affect the expectations of the competition. In this case, it is passive;

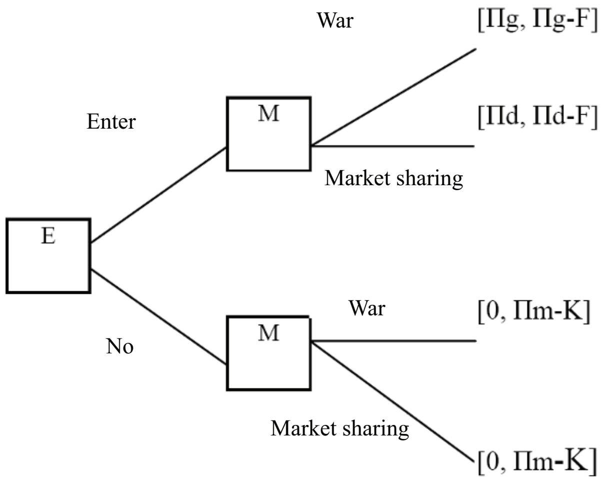
– the second situation where a "strategic" behavior is possible, meaning a threat strategy can be deployed. To give credibility, we will see that the threat must be fitted with a certain commitment from the established firm.

An entry game with two companies with no commitment from the settled firm

Consider a non-cooperative game, sequential with two stages as described in Figure 2.4. The game is represented under the form of a tree where at each extremity are given the gains of the players (the first are those of the established firm). At the first stage, the potential newcomer must decide whether to enter or remain outside of the market. If the newcomer remains outside, the established firm perceives a monopoly profit Πm. If entry occurs, we reach the second stage where the firm in place must choose between a price war, which leads to profits of Πg for each firm, or sharing the market with a duopoly profit of Πd for each of the firm.

We can suppose that Πm > Πd > Πg: the duopoly is profitable but less than the monopoly, whereas the price war is costly for both companies and mutually destructive. The determination of optimal strategies for each of these companies is done through mathematical induction, which involves going from stage 2 back to stage 1.

A monopolist (M) is already settled on the market. A newcomer (E) is about to pay a fixed cost to get set up, whereas the monopolist has already paid this. Before entering, E anticipates the reaction of the monopolist, which can either be a price war (threat of low prices) or a conciliation (setting a "normal" competition price). If the monopolist chooses to enter a price war, it would set such a low price that the newcomer would be unable to make a positive profit no matter its response. The monopolist may obtain, conversely, a positive profit despite the very low price, because it does not have that entry cost to recover. This game is represented by the following tree:



We suppose Πg < Πd, Πg-K < 0, Πd > 0 and Πm > Πd, K being the fixed entry cost for the newcomer. The perfect equilibrium of this game is "enter for E" and "share the market" for M. The perfect equilibrium does not include the threat of the monopolist as its threat is non-credible.

Figure 2.4. *Non-credible threat and perfect equilibrium*

Let us reason using the threats/promises that the two players can make before the game unfolds. Consider the couple of strategies (among the possible ones) that consist on the one hand for the newcomer to abandon the entry and for the firm to wage war in that situation. This pair of strategies "war in case of entry" for the settled firm and "remain outside the market" for the potential newcomer is a Nash equilibrium: no player wishes to modify the strategy given the one chosen by the other. However, we see that the war is not here a credible threat as it would not constitute the optimal response of the established firm in the event of an entry (inferior gain to the one resulting from sharing the market). This fact is known by the newcomer who, in this context, is not discouraged by the entry.

As [RAI 88] highlights, this situation is paradoxical due to the very idea conveyed by Nash equilibrium and it is the potential existence of a commitment that makes it possible to solve this difficulty. Indeed, the solution to this paradox is possible because of the introduction of the concept of perfect equilibrium[11], which, as we have explained previously, can be defined as the equilibrium that "excludes the possible actions which correspond to non-credible threats, given the strategies of others: these threats are the actions of players which would not be performed if players had time to execute them, because such an execution would go against their own interests" [JAC 85].

The game with commitment from the established firm

This model, which comes as an extension of the first one, describes a situation in which the firm can commit to actions that can contribute to giving credibility to the threat of war the firm could make to the newcomer upon arrival. This consists, for example, of a certain cost to prepare for war. These costs can be tied to the installation of a new production capacity or to advertising expenses. Suppose that the irrecoverable costs (c) are due to R&D expenses that have the strategic function of dissuading entry.

The potential newcomer must be convinced that the established firm will execute on its threat in case of entry. This supposes that the established firm has an incentive to apply its threat. To be credible, the threat must, for example, be accompanied by an "irrevocable" and

11 The only perfect Nash equilibrium is the one associated with (Πd, Πd): sharing the market is the best response by the established firm as Πd > 0 > Πg. The optimal strategy is on the side of the newcomer entering the market.

"irreversible" commitment from the established firm, in R&D or other investments (capacity, for example) [RAI 88]. In other terms, to be able to execute the threat in case of entry, the established firm must be sure of its "viability, in the sense that expenses caused by this policy are more than compensated by the surplus profits it makes" [JAC 85]. This expense does not affect the profit of the established firm if war occurs but, in the case it does not, its gains are decreased by the value of the R&D commitment. This model is only valid if the irreversible character of the commitment is known before the potential newcomer makes up his or her mind.

The model introduces an additional step in the previous game (Figure 2.4): stage 1 where the established firm must decide to invest in R&D or not. The game is described in Figure 2.5.

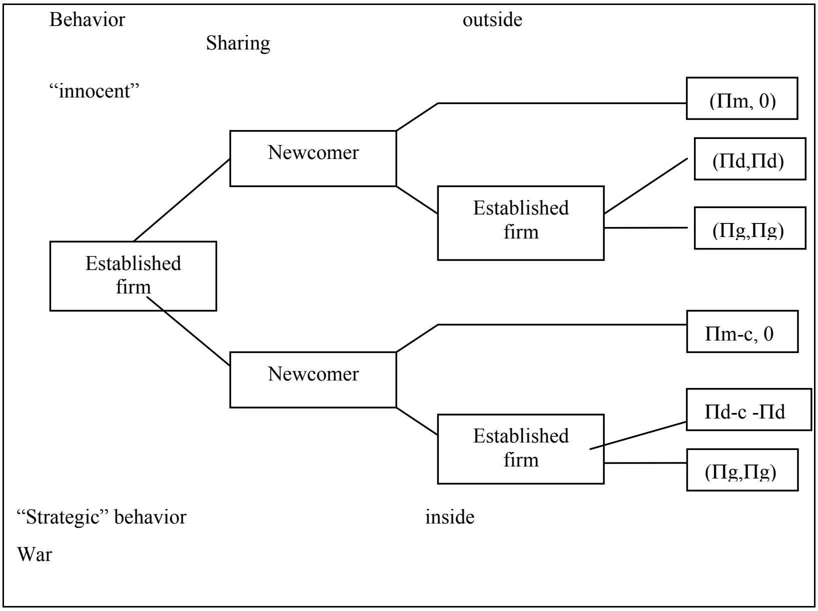


Figure 2.5. *Commitment by the established firm and barriers to entry*

In the new version of the sequential game, the threat of war is credible if, when the entry does occur, the decision of going to war does actually lead to a better profit than the decision to share the market, that is, if:

$$\Pi d - R\&D < \Pi g$$

If that is the case, the newcomer knows this and chooses to remain outside if the established firm commits: "do not enter" is its best response. The established firm is capable of maintaining this reasoning by putting itself in the position of the potential newcomer. It must then use mathematical induction to decide whether its optimal strategy is to remain passive or conversely to commit to R&D expenses. It will only adopt a strategic behavior if the monopoly gain with commitment and successful blocking of entry is higher than the one it would obtain in case of passiveness (duopoly and sharing), that is:

$$\Pi m - R\&D > \Pi d$$

The result is that the established firm will use its credible threat and block the entry if and only if there is a strategic commitment, which would have a cost that satisfies two conditions:

$$\Pi d - R\&D < \Pi g$$

$$\Pi m - R\&D > \Pi d$$

We arrive at: $\Pi m - \Pi d > R\&D > \Pi d - \Pi g$

This is on condition the threat of the established firm is considered to be credible: the difference between the monopolistic profit and the duopoly is higher than the cost of strategic commitment (R&D expenses) and the latter is itself superior to the difference between duopolistic profit and spoils of war. In such a case, the existence of a barrier to entry will result from the strategic action of the established firm [RAI 88].

2.3.2.2. *Cooperation on a market: the point of going from "simultaneous" to "sequential"*

Arrangements (cartels) surrounding prices and quantities are prohibited by fair competition authorities. Companies are sometimes searching for strategies that allow for arrangements without being uncovered as breaching anti-trust laws. In 1951, Markham [MAR 51] suggested the existence of market behaviors that can assimilate to such actions. He inspired works in the field of industrial economics that have modeled original forms of coordination. The arrangement occurs via the announcement of a high price serving as a "signal" or proposition for cooperation to competitors. This arrangement is conceivable granted the best response for competitors is to follow this upward trend (even if it is not proportional to the first one).

To illustrate this phenomenon, take the matrix example of companies E1 and E2 competing on a given market. Suppose that the companies have the choice between three price levels: p1, p2 and p3.

		Firm 2 (E2)		
		p1	p2	p3
	p1	(6,5)	(10,4)	(1,3)
Firm 1 (E1)	p2	(4,7)	(8,6)	(0, 2)
	p3	(3,1)	(1,3)	(14,1)

Examining this matrix shows us that the Pareto outcome (P2, P2) strictly dominates (p1, p1). However, (p2, p2) cannot be the result of a non-cooperative behavior from players in the frame of a simultaneousness of decisions (threats of unilateral deviations). If the game was sequential and the firm E1 was to play p2 for example, this signal for cooperation will be followed by E2, the best response to which is p2. Passing from a simultaneous model to a sequential one, improves the gains of both players realizing the price coordination that was not a Nash equilibrium outcome of the simultaneous game.

2.4. Conclusion

In this chapter, analysis was first performed with a static objective. Single period static models were presented. We studied zero-sum games with finite numbers of strategies. We presented a fundamental solution concept, which is that of the Nash equilibrium which, when it exists, constitutes a reasonable prediction of the solution of games. It contains the idea of optimality in game situations where there exists a strategic interdependence of players.

This first approach was completed in a second phase by formulations that take into account the existence of chronology in the decision and/or repetition of a game with "finite" or "infinite" temporal horizons. Sequential or repeated games can constitute, as we have seen, a useful context for a certain number of problems encountered in the reality of business strategy. Repeated games, when done so indefinitely, ensure cooperation without the need for a third party. In that, they represent a way to surpass the conflict between individual and collective interest. However, we will see in the next chapter how cooperation is a more complicated notion to analyze, especially when the number of involved players is high (more than two).

3

Coalitions Formation

3.1. Introduction

This chapter is dedicated to the procedures of cooperation and coordination and the way we can represent these types of procedures in the context of game theory. The existing concepts within this discipline are rich, particularly subtle, and often lead to lively debates within the field. The objective of this chapter is not to enter into these debates, which have very technical implications that are not in the spirit of this book. The idea is instead to offer a few concepts that can have interesting potential applications and be pertinent for management reflection within a coordination context.

In game theory, the two classical approaches, cooperative and non-cooperative, have emerged, with various hypotheses that can appear incompatible. However, some studies have shown how, by approaching cooperation through learning issues or sustainability (via repeated games, for example) or bargaining processes [NAS 50], it could lead us to establish a link between cooperative and non-cooperative strategies. More recently, an original approach (the theory of endogenous formation of coalitions) has progressively transformed into a veritable new and standard school of thought in the field, by introducing an original vision of cooperation from the concept of non-cooperative games [BAL 00, BLO 96, QIN 96]. It undoubtedly

Game Theory Approach to Managerial Strategies and Value Creation,
First Edition. Abdelhakim Hammoudi and Nabyla Daidj.

establishes a link and complements the classic approach to cooperation (what we call the theory of cooperative games), even if it opens the way – within the discipline itself – for a dispute over legitimacy. This leads us to question: which approach best represents cooperation mechanisms?

[MOU 81] defines the cooperative character of a game by the fact that players can group themselves into coalitions, where their common strategy is agreed in order to gain an advantage. The players are thus able to abdicate their decision-taking power and placing it in the hands of a representative authority. This indicates which coalition they belong to. The players of such a coalition can sign solid agreements and be held to them. These agreements can take the shape of promises they keep. Moreover, these promises may be sustained through threats they issue within the group (in case some betray their commitment). Within the framework of an important research axis of this approach (games with transferable utility), which refers to the theory of classic cooperative games, the benefits obtained by the coalition are spread among the members and how these benefits are shared will determine the *viability* of the coalition. The issue of viability within the coalition in regard to these hypotheses constitutes the research objective of this approach. Many methods of distribution and many systems for implementing the benefits of cooperation are then used (Shapley value in particular) and criteria for existence and stability of coalitions are proposed, among which is the core notion [MOU 81].

We briefly present this "cooperative" approach of coalition formation in the first part of this chapter. In the second part, we present the non-cooperative approach specifically through a simple conceptual context drawn from the formation of coalitions [BAL 00b, BLO 96, HAR 83, RAY 97, RAY 99]. This approach is, in our view, the most relevant for analyzing managerial strategy and has potentially contributed to enriching the thought process in the field. This chapter is inevitably slightly more "technical" than the previous chapters, although we have made every effort to make the contents the most pedagogical as possible. To that end, we focus on the notion of internal and external stability of a coalition, which are the most accessible concepts in this literature. The idea is to deliver the message as simply as possible so that the reader may comprehend the subtleties of reasoning and the usefulness of these concepts in the area of business strategy. These concepts have been chosen in relation to their vocation to be efficiently and easily applicable to concrete problems.

3.2. The notion of a coalition and the cooperative approach

The notion of a coalition has been approached through different lenses: political (formation of governmental teams, international relations), economic (treaties of free exchange, cartels, emergence of standards) and sociological (collective actors). What therefore is a coalition?

> "If there is a coalition, meaning if agents act together voluntarily, it is because they have an incentive to do so and not because they are spontaneously cooperative, something we could be led to believe from the term 'cooperative game'. The coalition allows each player to improve their gains in comparison to a non-cooperative situation. Each player therefore remains individualistic by participating in common action. To that end, the game of interactions that leads to a coalition surpasses the individual context. The members of the coalition commit to common rules and individual action is judged on the result it provides the group". [ABE 99]

The meaning we give to the notion of a coalition can vary from one context to the next.

This notion has been used to serve and enrich the socio-psychological and philosophical reflections and Hobbes raises the subject of coalitions in the state of nature. As explained by [PAR 10], "in many instances, Hobbes suggests that coalitions are necessary for facing a common enemy". Relying on this, Michael Taylor considers that the state of nature can be interpreted as an iterative game that leads to cooperation and a law of reciprocity: "if someone cooperates, my incentive is to cooperate; if he is aggressive, my incentive is to be aggressive". Although he analyzes the appearance of cooperation on different bases than Axelrod, Taylor comments his own result, saying it reminds him of "Tit-for-Tat".

Another acceptance of this notion of a coalition is the one we are given in the political context. Works by [WAR 82] and [LEM 94] suggest that the context in which game theory and, in particular, coalitions can be applied are international and interstate relations:

> "States are […] considered as rational actors, subject to the rules of the game. They seek, by working together, to each obtain more benefits than if they acted independently. Members participatory to a coalition bring resources to the group, the distribution of which is likely to change, further to 'parties' that are pitted against one other, coalition players or not. Finally, the formation of a coalition depends on the decision threshold to be reached, this threshold not always being evident in the field of international relations".

In the field of social sciences, coalitions can refer to another notion, which is that of a collective actor prone to permanent changes. "[The collective actor] has a variable geometry, is constantly redefining its borders, its alliances and its exclusion: it builds the social system by defining the rules of the game" [DE 03]. "The variety of coalitions and combinations is infinite, just like the variety of rules that shape it" [REY 04].

The economy gives us one or more meanings to this notion according to a specific context that is studied within it. The economic publications on coalitions are plenty. This chapter presents some of them.

Cooperative game theory does not offer a clear and unanimously accepted definition for the notion of coalitions. We will simply state that a coalition is generally seen as a set of players grouped in the name of a common interest. The players grouped in a coalition are meant to have the will to cooperate.

Two main categories of games are defined in the context of cooperative game theory. The first category is for games that are said to have transferable utility where the idea is to share the value generated within the coalition and the second category is for games characterized by non-transferable utility where we suppose that the players, when they cooperate, reach a set of possible payments. The question is to determine which payment vector will be accepted by all of these players.

Similarly, in the context of cooperative games, the general idea is that coalitions, already formed and generating value, must share that value between the members of the coalition. We do not focus on the manner or the upstream procedure that has permitted the creation of the groups. Attention moves to a distribution that "supports" cooperation in the sense of the "agreement", in general a distribution proposition of value, is accepted by all members of the coalition.

This definition by [GON 15] reflects the spirit of such a procedure.

> "Cooperative game theory attributes value to every coalition (cooperative games with a transferable utility) or a set of possible payments for each player (cooperative games with a non-transferable utility). The theory assumes that most of the time, players play together and look for individual payment that can be taken into account in the best way possible, searching for what each player could have obtained from playing in such a sub-coalition. Depending on the allocation rules provided, it is possible to define which sub-coalitions have the most incentives to prevent the proposed payment compared to what they would be able to protect themselves. The hypothesis that each coalition is capable of banning payment to each of its players, independently from the way in which other agents are established is one of the criticisms of this theory: cooperative games do not consider externalities. This is why a cooperative games

> theory has been developed, making the value of a coalition dependent on the division of players outside the coalition. However, this theory which is more difficult to use, does not allow a player to be part of two coalitions at the same time, which eventually proves to be restriction to the framework that was originally intended to be more general". [GON 15]

If we wish to easily describe the primary line that constitutes the general spirit of this approach, by avoiding numerous bifurcations and other refinements, which exist in the prolific literature that is associated with it, we will say that cooperative game theory aims to determine the conditions of viability of a coalition through a good distribution of the value it creates. In most cases, it will in fact be a matter of testing this property on the greatest coalition, the one that includes all present players.

The cooperative approach focuses on the mechanism of forming coalitions, meaning the way players proceed to find a common interest group. The question is primarily to know if the players of an existing coalition can remain united within the coalition by finding a unanimously accepted agreement in regard to the created value. In other words, it is about avoiding coalition members being unsatisfied with their share of value, leaving the coalition and playing independently. In an established version of the theory, it is a matter of avoiding defection from individuals, but also the formation of sub-coalitions (groups within a larger group of players) that could play independently of the rest of the players of the community. In the end, the idea is to find a distribution agreement that can:

H1 – satisfy all individuals in the sense that no one can obtain alone a better payoff than what the coalition offers him or her;

H2 – satisfy all potential coalitions formed of players within the larger coalition and who could find more advantageous ways of creating value by playing alone.

When a coalition refuses an allocation of the gain proposed by the greater coalition, this means that it anticipates that by leaving the community of players, it ensures itself a greater gain than by remaining within the greater coalition. Such a coalition is called a "blocking coalition" in reference to its refusal to accept the allocation or the "agreement".

Many concepts and variants have therefore been proposed to analyze cooperation in such a context. Often, these concepts are of great mathematical complexity. It is not about listing them all here. However, in order to give an idea of certain concepts and the reasoning that they implement, we take an example of the concept of "core", which, along with the notion of Shapley value, is a representative concept of cooperative game theory.

These concepts are defined in a class of game we call characteristic games.

Consider a set N of n players. The n players decide to unite forces by grouping into a (great) coalition. The great coalition creates value and enables us to achieve a (total) gain, of level $V(N)$ through the cooperation of all its members. The gain $V(N)$, called value of N, is supposed to be the maximum that coalition N can obtain.

Consider the possibility that appears as an alternative to coalition N, coalitions grouping a limited number of players N, be S a given coalition ($S \subset N$). The framework hypothesis according to which each coalition or individual in the community is assigned a value defines what is called games in characteristic form. (see in the following).

We suppose that a coalition S can guarantee itself, independently of others, so by playing alone rather than relying on other players N/S (the players who are in N but not in S), a (maximal) gain $V(S)$, that we will call value S.

Similarly, a player $i \in N$ can guarantee itself a gain $V(i)$.

This previous description corresponds to the representation of the class of games in characteristic form, which constitute an important branch of cooperative game theory. To summarize, a game under characteristic form is the datum of a couple (N, V), where N is a set of n players ($n \geq 2$) and V a function *said characteristic that associate*s to each coalition S a value $V(S)$.

The question we can ask is whether there is an allocation of value $V(N)$, which allows both individuals and coalitions of players N to accept the allocation and give up on leaving the community individually or collectively (by forming partial coalitions). In the end, it is a matter of finding a "good" allocation of the community cake[1]. We are looking for sharing that gives each player a piece of cake that is better than what he/she could achieve alone: i) it can be manufactured by its own means and simultaneously, ii) it gives to any coalition coming out of the community and which plans to withdraw from this community, a total share (made up of the addition of individual shares) greater than the cake that this coalition can make on its own (using the capacity resulting from the union of its members).

Certain basic concepts have been formally defined to resolve this question. The first concept is the notion of *imputation*.

Consider a *share*, *noted as* $(x_1, x_2, \dots, x_n)$ of the overall gain $V(N)$

DEFINITION 3.1.– *The allocation of gains* $(x_1, x_2, \dots, x_N)$ *is an imputation if it verifies the following two properties H1 and H2*:

$$\begin{cases} \sum_{i=1}^{n} x_i = V(N) & (H1) \\ x_i \geq v(i), i = 1 \dots, n & (H2) \end{cases}$$

The property H1 simply states that the vector $(x_1, x_2, \dots, x_N)$ is an allocation of the exact value created by the firm: we must only share what we have by cooperating, no less, no more. The property H1 defines what we call individual rationality. One only commits in a collective project if one gets at least what he or she could get in the context of a collective action.

1 Note that even if it corresponds (by similarity) to the reality of a large number of economic problems analyzed through cooperative games, the term "cake" should be understood as a pedagogical tool used here to set the stage. Further along we will give examples where it is a matter of dividing costs.

H2 states that it is necessary through allocation $(x_1, x_2, \dots, x_n)$ to satisfy all individuals in a sense where none can solely obtain a better payoff than what the coalition offers him or her. An imputation is therefore an allocation that is accepted by all individuals.

Take the following example: suppose that two different students living in two different areas decide to take a taxi together. The taxi is ready to drop them at their houses for a total fare of 30 euros. The first student (player 1) can alone take a taxi for 18 euros, whereas the second (player 2) would have to shell out 16 euros in that event. It can be assumed that the duration of the journey is the same as any journey taken in a group or individual taxi. Moreover, we can suppose that this cooperation (sharing a taxi) generates a total cost $V(N) = 30$ (or –30 if we wish to maintain the strict intuitive meaning of "value"), whereas individually they pay $V(1) = 18$ and $V(2) = 16$. The set of possible imputations is therefore the set of all allocations (x_1, x_2) that verify $x_1 + x_2 = 30$, $x_1 < 18$ and $x_2 < 16$. Note that we can adopt a large or strict inequality in H2 depending on the state of mind of the players: can they accept to remain in the coalition if they are offered exactly what they would get alone? In the case of our students, it all depends on the enjoyment they experience from sharing a cab ride together, which in this case is a non-economic criterion. We see that these types of arrangements exist. Moreover, there is a collective saving of 4 euros made in by cooperating in comparison with individual action. The different existing imputations differ by the ways in which this overall gain is divided between the two players.

One possible imputation, as we have just seen, is an allocation of value that protects the community (or the greater coalition) against individual actions. If we push the logic further, it would be tempting to ask whether there are ways to divide the value, which not only dissuades individuals from refusing, but also the sub-groups of individuals that would form coalitions and play outside of the greater coalition. Such an apportion would of course be more ambitious and more demanding than an imputation and would define the notion of *core*, one of the fundamental concepts in cooperative game theory introduced for the first time by Gillies in 1953 [GIL 53]. The core is a set of possible allocations that have the previous properties that can be summarized in the following definition:

DEFINITION 3.2.– *An allocation of gains* $(x_1, x_2, \ldots, x_n)$ *belongs to the core if it verifies the following three properties H1 and H2:*

$$\begin{cases} \sum_{i=1}^{n} x_i = V(N) & (H1) \\ x_i \geq v(i), i = 1 \ldots, N & (H2) \\ \forall S \subset N, \sum_{i \in S} x_i \geq V(S) & (H3) \end{cases}$$

This definition includes, first, the condition for the allocation to be an imputation (H2). Moreover, it stipulates that it is not only individuals who cannot block the allocation but also coalitions of individuals (H3).

The core can of course be empty. If this were the case, it would mean that the community was incapable of finding an allocation that would be unanimously accepted by all individuals and coalitions and would therefore be unable to unite its members around the common collective project. The community is then condemned to burst into individuals or coalitions each playing independently of the others.

We can easily deduce a necessary condition for the core not to be empty. The following condition must be verified:

H4 – The greater coalition creates a value that is equal or superior to the sum of values that a coalition S and its complementary N/S can ensure by playing separately: $\forall S \subset N, V(N) \geq V(S) + V(N/S)$.

We call this property superadditivity and the game under the characteristic form V is called superadditive. If the total value created by a coalition and by its complementary coalition when each of these coalitions act alone is superior to what the union of these two coalitions can create, the greater coalition can satisfy (in an allocation $V(N)$) at most one of these coalitions. In other words, for the core to exist, the *union*, between both complementary coalitions, no matter the coalitions, must *be the stronger force* in the sense where S and the greater coalition create better value. Otherwise, it is simply not efficient to regroup.

Consider a classic example. Let us name three towns: A, B and C that are looking to coordinate to build a common electric network. Collaborating on this will reduce the costs that come from infrastructure and network and thus create substantial collective savings for the community of towns. Each town has proceeded to its own cost-assessment for an individual array. We suppose that the costs associated with individual action are (in an unspecified currency): $CT(A) = CT(B) = CT(C) = 120$.

If two towns unite to build the network independently of the third, the total cost would be: $CT(AB) = 170$, $CT(AC) = 160$, $CT(BC) = 190$.

Lastly, if the network is made *via* the collaboration of all three towns, the total cost would be: $CT(ABC) = 255$.

The allocations that belong to the core are by definition all possible splits of the cost $CT(ABC)$, which satisfy the towns individually (in a sense that they are not tempted to build their own network) and any eventual groups of two towns in the aim of building the network independently of the third. An allocation (x_A, x_B, x_C) belongs to the core if:

$$\begin{cases} x_A + x_B + x_C = 255 \\ x_i \leq 120, i = A, B, C \\ x_A + x_B \leq 180 \\ x_A + x_C \leq 175 \\ x_B + x_C \leq 190 \end{cases}$$

We can verify the allocation (85,85,85), which is a egalitarian partition of the cost of 255, satisfies the previous system of equalities and inequalities, and thus belongs to the core. The community therefore has the possibility, through this specific allocation of the total cost, to build the network in a more efficient way, by associating all of its members. It is not only one allocation that allows for the participation of all the community to this project. All vectors of allocations that verify the previous system (core properties H2 and H3 of Definition 3.2) may be acceptable by the members of the community. Which allocation will be selected? This question brings us not only to the selection of the allocations accepted by all players, but to some degree to the outcome of a negotiation between the members in order to select, among the allocations of the core, what allocation has to be finally chosen. This issue goes past the scope of the standard analysis of the core (with the exception of the Shapley developments, see Box 3.1). The fundamental issue in the core theory is the existing issue of the core, that is its non-vacuity. Therefore, one very important branch of literature deals with determining the mathematical priorities that guarantee the existence of a core for different game typologies, under characteristic form, with or without transference of utility (for instance, the groundbreaking works of Bondareva [BON 63] and Shapley [SHA 71]). Often, the complexity of the technical developments and the mathematical demonstrations make them inaccessible to an uninitiated public.

The Shapley value relies on the representation under characteristic form of a game (presented previously). The procedure associated with the Shapley value consists of defining axiomatically a rule of allocation that defines the solution of a game. In other words, we are capable, through this rule, of associating a unique solution to a given characteristic game, meaning an allocation that specifies the part of the Shapley value allows, among other things, to solve (axiomatically), a problem that does not deal with the concept of core: what solution should we choose among the acceptable allocations? The axiom linked with this procedure imposes condition H1: the sum of the parts of each player must be equal to *V(N)*. The second condition states that two symmetrical players or substitutes must have the same share in the proposed allocation. The notion of substitute players (or symmetrical players) includes the definition according to which these players are characterized by marginal contributions equal to all potential coalitions (the marginal contribution to a coalition S is defined by $C_i(S) = V(S) - V(S - \{i\})$. The third condition states that to a null player (i.e. a player whose marginal contributions are null) must be affected by a null share. The final condition states that the rule must be additive in the sense that the solution of a game, defined as the sum of two games (in the sense of the sum of the characteristic functions), must be equal to the sum of the solutions to the game. Shapley [SHA 53] shows that by relying on these axioms, we can determine a unique allocation that constitutes the solution of the game. This solution is the one that at each game *(N, V)* associates for each player a share of the global value equal to a certain sum determined by his or her marginal contributions to all potential coalitions. Formally, if we state *m(S)* the number of potential coalitions that contain i and are the same size as *S*, the solution (allocation) $(x_1, x_2, \ldots, x_n)$ of the game is given by $x_i = \frac{1}{n}\sum_{S\subset N}\frac{C_i(S)}{m(S)}$.

Box 3.1. *The Shapley value*

Cooperative game theory has shown good dispositions to be applied to situations where one must look for acceptable and fair cost sharing allocations. Numerous applications have been proposed and some have played an important historic role in the development of the discipline by demonstrating that the tool can sometimes have an unsuspected operational scope (see Box 3.2 for the applications of Shapley value).

The Shapley value (or the Shapley–Shubik power index in its applied version) has been often used in the resolution of real problems, for example questions pertaining to voting, allocating costs where certain famous applications in the United States have become textbook cases: distributing costs between the divisions of aeronautic manufacturer McDonnell-Douglas, distributing the costs of renting a phone line across an American University, financing irrigation projects in Tennessee. Owen [OWE 82] focused on landing rights for air travel companies at airports. They demonstrate how this theory of cooperative games can be offset from reality. Real-world rights make it more beneficial for larger planes: smaller ones are taxed relatively higher.

Box 3.2. *A few applications for the Shapley value*

Cooperative game theory, in its classical conceptual framework (see the book by Von Neumann and Morgenstern [VON 44]), does not consider the externalities produced by other players on a blocking coalition, deviating from the agreement. Under which hypothesis associated with the reaction of others to scission does this coalition obtain its value? The theory does not fully answer this question. In its original version, the book [VON 44] considers that everything occurs as if the game between a coalition and its complementary were a zero-sum game and the value obtained by a coalition was simply the gain it obtained from this game.

The absence of interactions between the formed coalition and the players outside of it, a hypothesis that is widely present in the classic cooperative approach of the formation of coalitions, does not always allow the theory to be applied to real contexts where there are strategic interdependencies. The applications we will present later where players through both their non-cooperatives and cooperative strategies are in situations of interdependence show how the hypothesis of non-independency of the coalition in respect to the outside can be difficult to sustain.

3.3. Emergence of cooperation: from collective rationality to individual rationality

3.3.1. *Some illustrations*

To introduce the somewhat complex notion of coalition formation in a non-cooperative context, it would be useful to start with some concrete examples to get an idea of the different applications of this approach.

The non-cooperative approach assumes that the coalitions that are formed are not those formed *ad hoc* but rather result from the *ex ante* sovereign decision of players to coordinate. The decision to adhere to a coordinated, collaborative project, or even, in some cases, choosing the coalition one wishes to belong to, is a decision that is made by each player without constraint (stipulated by contract) to respect it.

The decision to “adhere” or to “cooperate” is then a strategic variable selected within the context of a non-cooperative game.

Coalitions are formed as a result of a non-cooperative voluntary adhesion game. Coordination on the adhesion variable does not necessarily imply a commitment from players (this field is closer to the cooperative approach of coalition formation). We generally say that coalitions are formed endogenously.

The objective for players is to be part of a coalition that ensures them the maximum possible gain, taking into account the rules of the game. In other words, they decide to join a coalition with the goal of maximizing gain, knowing that their gain is dictated by the interactions with the decisions of the others, as other players must also make their decisions (adhesion, choice of a coalition, etc.) independently, that is without coordination.

After all the players have made their decisions, coalitions appear and constitute a *coalitions structure* (all coalitions formed at the outcome of the game). The property of these coalitions is that they are formed “spontaneously” without the need for any negotiation and/or an agreement contractually binding the members of a coalition.

The types and characteristics of emerging coalition structures depend on the rules of the coalition formation game, which were defined. In other words, they depend on the chronology of decisions made (simultaneousness/sequentiality) and the type of decision the players are supposed to make: this can range from an “adhere or not” strategy to a project (binary decision as in the case of the format battle) to choose a coalition to belong to[2].

As an introduction to coalition formation theory, we limit ourselves to simple games in which adhesion decisions are simultaneous and where the strategy space is reduced to the binary choice: to adhere or not to adhere to a given cooperation project (a cartel project, a strategic alliance, etc.).

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2 This type of game is quite complex and will not be discussed in this book (see [BLO 95] and [BLO 96]).

We begin by defining two types of motivation that favor the emergence of cooperation. We must distinguish between (1) *collective* incentives for cooperation, that is the profitability of co-operation in the sense of the collective common interest, which is a necessary condition for considering any collective action, and (2) *individual* incentives for cooperation that reflects the incentive of an individual player to adhere to cooperation when this said cooperation is implemented. This latter condition is one of the conditions for the effective implementation of the cooperation. The first concept (1) ensures the collective rationality to cooperate and the second (2) ensures individual rationality to participate unilaterally in cooperation.

3.3.2. *Emergence of cooperation*

Proposing a cooperation project requires, at least from the point of view of the collective, interest from the coalition to be formed so that all partners must find themselves in a better situation than the current situation of non-cooperation. In other words, the outcome of the future cooperation must Pareto-dominate the outcome of the current non-cooperative alternative. This property defines a collective rationality criterion.

For example, it is rational to think that the members of the OPEC (Organization of the Petroleum Exporting Countries) have a collective incentive to create that organization in the sense that they are certain that the situation where they coordinate production quotas leads to better revenue than the alternative situation where there is no coordination. It is also rational to believe that companies only commit to a strategic alliance to, for example, collaborate on an R&D project, if that operation is more profitable for them than the situation where there is no cooperation.

Collective rationality, which encourages implementing a cooperation project, is often referred to as “cooperation profitability”. The concept of profitability can be applied to a “partial” collaboration involving a sub-set of players or a total cooperation involving all players present (formation of the *great* coalition). Thus, a coalition is only profitable if all its members obtain a better profit in the coalition than in the absence of any cooperation (situation of non-cooperative *status quo*).

As an example, consider three identical firms in a market with imperfect competition on quantities. The inverse demand is given by $P(Q) = Max(a - Q, 0)$, where $Q = q_1 + q_2 + q_3$ and $a > 0$. The marginal cost of production is supposedly null.

A cartel of size *n* is said to be profitable if the profit of all of its members is superior in the situation where the cartel is formed rather than all the firms being independent, meaning the situation where the *status quo* sees all firms competing.

Let us demonstrate that any cartel of size 2, meaning it is composed of two companies, is not profitable. Consider the cartel $C = \{1,2\}$. The competition on the market consists of a confrontation between two firms: firm C, which plays as one single player, and company 3. The solution to this confrontation is a Nash equilibrium in quantities opposing both players.

Let us calculate this equilibrium. The cartel maximizes $\pi_1 + \pi_2$ in relation to the variables q_1, q_2 and firm 3. We obtain at equilibrium q_1, q_2 (we assume that the cartel spreads the production by affecting $q_1 = q_2 = q$) a firm's profit in comparison with its production q_3. The Nash equilibrium is the solution to the system of best reactions (the best reaction from the cartel to q_3 and the best reaction of firm 3 to q).

At the equilibrium, the strategy of the cartel is given by $\bar{q} = \frac{a}{6}$, and the profit of its members is $\bar{\pi}_1 = \bar{\pi}_2 = \frac{a^2}{18}$.

Furthermore, we can verify that when all firms are independent, the Nash equilibrium leads to identical levels of production: $q^* = \frac{a}{4}$ and identical profits $\pi_i^* = \frac{a^2}{16}, i = 1,2,3$.

We observe that $\overline{\pi}_i < \pi_i^*$. Cartel C is therefore not profitable. There is no incentive to form a cartel. We can verify that this result is true for any cartel of size 2, the model being completely symmetrical (the companies have identical costs).

The result is predictable for the following reason. In forming a cartel, two firms form a single entity; the subsequent situation on the market is similar to that of a competition between two identical companies (since the cartel acts as a single entity, the strategic variable being the total production of the cartel that is allocated *ex post* between the two firms). At equilibrium, everything happens as if the cartel was receiving half of the "potential profit" of the whole industry (which is higher than the industry potential profit associated with the *status quo*), and firm 3 receiving the other half. However, in the initial situation (*status quo*), each company receives a third of the "potential profit". If the total profit of the industry associated with the case of the cartelization (of the two firms) is not sufficiently high compared to the total profit of the industry in the *status quo* (which is the case here), then the cartel as an entity will obtain a smaller profit than the aggregate profit obtained by its members in the initial situation.

The existence of a collective interest to cooperation does not necessarily mean that this cooperation will happen or that it will be *sustainable*. The simplest example is the one of the prisoner dilemma where there is a collective incentive to cooperate (cooperating collectively is better than not cooperating collectively) but where cooperation will not take place for reasons of individual rationality. It is the case for any game where some players can be tempted to profit from the cooperation without actually having to suffer the cost of its setup. The players who adopt this behavior that makes cooperation fail (even when it leads players to a better profit than the initial situation) are referred to as "free riders".

This phenomenon jeopardizes the realization of a cooperation project in particular when cooperation among part of the players generates a positive externality for the remaining players outside this cooperation. This is the case, for example, of some collusive price agreements, which by softening the competition on the market ends up benefitting more the firms that are not part of the resulting cartel. This is also the case for a coordination of production quotas (for instance, OPEC cartel), which allows companies or countries outside the cartel to benefit from rising prices while maintaining their strategic control over their own production quantities (thus a generally higher production than the members of the cartel, sold at a relatively high price due to the coordination between the others). The free rider phenomenon appears when renouncing one's strategic independence (as part of accepting to need to cooperate) involves a cost (associated with losing strategic *flexibility*). The players can be tempted not to support this cost if they are certain that other players will setup the collaboration.

When it is certain that a number of players have already adhered to the coalition, the individual decision to adhere is the outcome of a choice between the following:

– the "sacrifice" required by the coalition, expressed in terms of cost generated by one's loss of strategic freedom. For a quota agreement, for instance, this cost depends on the size of the production restriction expected by the cartel from the new member in relation to what the latter could be producing freely;

– the advantage of adhering to the coalition, expressed in terms of individual marginal contribution from the collaboration. In the example of the quota fixing agreement, this marginal contribution would be the marginal price increase generated by the addition of a new member.

If the "sacrifice" outweighs the "advantage", the outside player can decide not to adhere. This incentive is reinforced as the external effects of the collaboration are stronger and stronger.

3.4. A simple conceptual frame of analysis for cooperation: notions of internal and external stability of a coalition

To understand how arrangements between companies occur on a market with no prior negotiations or explicit agreements and commitments, [DAS 83] and [DON 86] have proposed a frame of analysis that suggests that collaborations can only appear because there are individual incentives to be part of it. Although collective rationality explains why it is profitable for a collective action to take place rather than not, the individual incentive for a member to participate explains why certain cooperations resist more than others the opportunistic behaviors of members who deviate from the agreement when they know others are respecting it.

The classic founding analytical frame now used to understand the appearance of cooperation in the absence of irrevocable binding contracts was created as an answer to questions surrounding cartelization in the industry. A cartel generally defined as a group of independent companies that decide to agree on strategic variables such as price or market shares. Thus, the constitution of a cartel, while it supposes communication between businesses, does not involve a loss of sovereignty and the loss of strategic freedom that comes with it, as they would in other forms of joint venture or merger acquisition type operations, which generally result in the creation of a new entity acting like an individual company on the market [JAC 89].

Stability analysis of cartels has evolved from a static comparative approach. The idea is to specify the incentive for a firm to participate or not in an explicit cooperation in the industry, when others have already made their choice. [DAS 83] proposed the criteria supposed to account for this adhesion to a cooperation project depending only on the incentive for a firm (or more generally a player) to join or leave a formed coalition. The players can therefore decide to cooperate or not depending on their strategic interests and there is no restriction or clause forcing them to stay in or leave the coalition they chose to join. If a coalition is formed, it is the result of voluntary strategies by the players, which end up being optimal: a player having joined a coalition will not change his or her mind if he or she is sure that all others keep theirs, and another player who chose not to join will not change his or her mind, while the other players are still undecided. [DAS 83] rely, in their founding article, on a specific economic model of cartelization, which we will not present here[3].

Lastly, note that although the criteria for internal and external stability considers a formation process of a game of simultaneous adhesions, there is an entire branch of literature on endogenous coalition forming that considers sequential formation games, in line with the works of Bloch, Yi, Ray and Vohra (Box 3.3).

The players can, for example in this context, sequentially decide on which coalition they wish to join and go back on that decision at a later stage, etc. The possibilities for variations of actions in this type of game can then be rich and more or less adapted to the reality of certain mechanisms of coalition forming, which we can observe in real-world cases. Bloch proposes a formation model in which a player begins by proposing a coalition S to other players. The players respond to this offer sequentially by rejecting the offer or accepting it. When a player rejects the proposition, he or she must make a new proposition. If all players accept, coalition S is then formed and leaves the game to give way to a similar process involving the remaining players (a new player from coalition N/S makes a proposition, etc.). Bloch demonstrates that this sort of game leads – under certain conditions such as when there is player symmetry (all players are identical) – to a unique equilibrium coalition. These conditions can be determined via a simple algorithm: each player chooses the size of the coalition that maximizes his or her gain, taking into account the sizes of the previously formed coalitions. Note that following in Bloch's footsteps, Ray and Vohra generalized this game and identification mechanism to non-symmetrical contexts, where all players are not identical. Lastly, we can observe that these typologies of formation games are similar in spirit to negotiation games, like that of Rubinstein's. The idea is to negotiate the coalition according to two principles:

3 The authors place themselves in the context the model of price leadership [MAR 51] where a cartel that does not include all business on a market, sets a market leader price, in anticipation of the quantities produced at that price point by all business not belonging to the cartel (these businesses are *de facto* price takers).

1) each player chooses the coalition he or she wants to form;

2) a coalition can only be concluded if all members accept to join.

Box 3.3. *Coalition forming via sequential games*

3.4.1. *The concept of stability as a basic property of cooperation*

In their simple presentation, the concepts of internal and external stability explain how a cartel can form and how it cannot integrate all businesses in the industry. The idea is therefore to explain how we arrived at an industry structure where a coalition is forming that includes a sub-set of businesses of the industry (the cartel) and a sub-set of firms that set their own prices independently. The latter is often called the "fringe group". The cartel is then said to be "internally stable" if none of its members obtain a profit higher than the profit that would have been obtained by unilaterally joining the fringe to decide its market offer freely. It is said to be "externally stable" if no firm from the minority group has an incentive to unilaterally join the cartel. A cartel is said to be "stable" if it is both internally and externally stable.

Let us assume the presence of N firms and assume a coalition (cartel C_n) including $n \leq N$ businesses is formed. We suppose that there is an agreement or a voluntary coordination of the members of this cartel on the strategic level of the market variable (price or quantity, for example). Outside companies are totally independent and play in a non-cooperative manner among themselves and in relation to the coordinated cartel strategy. This independent set of businesses, called fringe groups, includes $N-n$ business and is noted as F_{N-n}.

Note that $\pi_i(C_n)$ is the profit of a given business i, $i \in C_n$ or $i \in F_{N-n}$.

Let us define coalition C_n, which is:

1) internally stable if and only if : $\forall i \in C_n, \pi_i(C_n) \geq \pi_i(C_n / i)$;

2) externally stable if and only if: $\forall j \in F_{N-n}, \pi_j(C_n \cup j) < \pi_j(C_n)$.

The internal stability of a coalition guarantees that the latter cannot disintegrate via unilateral defection of its members and external stability ensures that the cartel reaches its maximum size in the sense that no outside business wishes to join it. The coalition can therefore not extend with new members.

3.4.2. *The stability as an equilibrium property of a game*

The principle of the non-cooperative approach to coalition forming is that of cooperation as a result of strategic choices by free players. The formation process for coalitions is specified and the present coalitions are therefore the results of choices by players. This approach considers cooperation to be an endogenous situation resulting from a game where one of the strategies the players must play is to decide whether or not to participate in the cooperation. The decision to participate (or not) in the project is an "optimal" strategy for any player in a context of interdependence. The strategic interdependence in this type of game derives from the fact that the gain obtained by a player depends not only on his own decision (adhere or not) but also on those of the others, that is, members who have decided to join its coalition and members who have decided to belong to the opposing coalition. Ultimately its gain will depend on both the size of the coalition to which it will be up to the size of the one that will make him face and identity (i.e. the characteristic) of the members of these two coalitions.

The criteria for external and internal stability of a cartel or a coalition [DAS 83] are simply the properties that a structure (coalition and fringe) have to satisfy at the equilibrium of a certain game, which we define as follows:

Consider a game $J(N,(A_i)_{i=1,\ldots,N})$ in two stages where:

– N is the number of present players;

– $A_i = \{1,0\}$ is the space of possible actions for player i at the first stage of the game.

The decision $a_i = 1$ of a player i simply means he or she adheres to the coalition, whereas $a_i = 0$ means he or she declines and chooses to remain independent.

The stages of this game $J(N,(A_i)_{i=1,\ldots,N})$ are the following:

– Stage 1: The companies simultaneously announce their decision to adhere (decision $a_i = 1$) or not (decision $a_i = 0$) to a coalition project (or cartel).

– Stage 2: A coalition of size $n \le N$ is formed. It is composed of every business that chose 1 (number n). An oligopolistic competition takes place between the cartel and the outside businesses (the fringe group, composed of the businesses that chose 0).

At the second stage, there is an oligopolistic confrontation between $N-n+1$ businesses. The businesses that are members of the coalition $C_n = \{1,2,\ldots,n\}$ cooperatively determine their level of strategic variable. The members of the coalition therefore coordinate even though they are playing non-cooperatively as a single entity against the $N-n$ fringe. For a set value of n, the outcome of the second stage is a Nash equilibrium between players C_n, $n+1$, …, N.

One outcome of the two-stage game is the value of:

– a coalition C_n including all firms that chose $a_i = 1$ at the first stage;

– a fringe F_{N-n} of independent firms having chose $a_i = 0$ at the first stage;

– strategic variable levels (prices, quantities) resulting from the oligopolistic competition of the second stage of the game.

To choose its action at the first stage of the game (to adhere or not), each business anticipates the consequence of its own strategy on the outcome of the second stage. It anticipates its gain depending on one or the other strategy, knowing that this gain also depends on the actions of others (how many are adhered and how many are in the fringe).

We are looking for a perfect equilibrium to this game.

The fact that an outcome of the game in two stages is a perfect equilibrium means that the considered firm (member of the coalition or of the fringe) has no incentive to deviate unilaterally from its adhesion strategy when the others maintain theirs, considering the anticipated gains of the second stage. In other words:

– a business that chose $a_i = 1$ and therefore adhered has no incentive to unilaterally change strategy (and choose $a_i = 0$) when all other strategies are set;

– a business that chose $a_i = 0$ and therefore decided to not adhere has no advantage in unilaterally changing strategy (and choose $a_i = 1$) when all other strategies are set.

The resulting cartel from the perfect equilibrium of this game verifies the internal and external stability criteria as stated by [DAS 83].

One outcome of the two-stage game is that certain businesses have said *Yes* to adhering, and others have said *No*. An outcome is therefore an industrial structure of coalitions including a coalition C_n of size n with $C_n = \{i / a_i \equiv 1\}$ and a fringe of size $N - n$ with $F_{N-n} = \{i / a_i \equiv 0\}$.

This outcome is an equilibrium if and only if:

1) a company that said *Yes* has no interest in changing its decision (to say *No*) when all others maintain their decision (internal stability);

2) a firm that said *No* has no interest in changing its decision (to say *Yes*) when all others maintain their decision (external stability).

Box 3.4. *Internal and external stability*

To simply understand these concepts, the next section presents a few numerical examples put into perspective in the context of real situations observed from economic reality.

3.4.3. *Examples*

3.4.3.1. *Cartelizations and mergers in an industry*

Imagine three petroleum companies each having a gasoline station located within a given stretch of the highway[4]. A project of a collusive price agreement (collusive price level) is proposed. The stations must simultaneously decide if they adhere or not to this operation. The price coordination allows them to get out of a competition situation that the stations consider to be too harsh. These stations believe that the softening of competition on this segment is made all the more possible and even easier for the following reason: the consumer is totally captive since obtaining supplies outside these three stations generates a significant cost to him because he would be obliged either to leave the highway (and pay a toll) or to travel a relatively large distance to reach an independent station (assuming the fuel supply allows for it). The agreement on the market at the outcome of adhesion decisions taken independently is not limiting. In the first stage, the stations announce freely and simultaneously their will to adhere or not to this operation. Cooperation appears if at least two stations set the cooperative price.

With the decisions of the first stage being taken, the prices are set at the second stage and the stations capture their market shares and obtain their final profit. We assume that the stations have the capacity to anticipate their profit levels depending on the structure of the coalition that prevails at the first stage of the game.

The possible coalitions that can emerge at the outcome of the game are (1,2), (1,3), (2,3), (1,2,3) and the singleton coalitions (1), (2), (3). Singleton coalitions emerge when at least two companies have refused to adhere to the price coordination.

4 This example is discussed in further detail in Chapter 6.

We will call *status quo* the structure of coalitions composed of singleton coalitions. The emergence of such a structure involves the persistence of the initial scenario where there is no cooperation in the industry.

The *status quo* leads stations to the following profits:

$$\pi_i[(1,2,3)] = 4, i = 1,2,3$$

To each coalition structure is associated a profit for each firm, which corresponds to the one it obtains at the second stage of the game, knowing that its performances on the market depend on its decision in the first stage and on the decisions of others.

Note that $\pi_i[(S), N/S]$ is the profit of i when S is formed and N/S remaining independent businesses.

The profits obtained depending on the structure of coalitions that takes place are given by:

$$\pi_i[(1,2,3)] = 10, i = 1,2,3$$
$$\pi_i[(i,(j,k)] = 8, i, j, k = 1,2,3, i \neq j \neq k$$
$$\pi_j[(i,(j,k)] = \pi_k[i,(j,k)] = 6, \text{where } i, j, k = 1,2,3, i \neq j \neq k$$

The above-mentioned profit levels reflect a well-known economic and industrial situation, which is often confronted by a certain number of facts in economics. The idea is that if the price agreement softens the competition and allows participating firms to improve their profits in relation to the situation where there exists no cooperation (situation of *status quo*), it profits much more firms that are outside and observe cartelization carried out by other firms. These firms can then profit from the general rise in prices generated by the arrangement to increase their prices to be less than the cartel's and this allows them to receive a greater market share than the firms belonging to the cartel.

To make a decision at the first stage of the game, stations know the profits they obtain at the second stage of the game. The strategies used at this stage (1 for Yes and 0 for No) correspond to the Nash equilibrium of this stage, if this equilibrium exists.

We can give a matrix representation of the game by supposing, for example, that the line represents the decision of station 1 and the column represents the possible decisions for stations 2 and 3.

Decisions F2 and F3 Decision of F1	1,1	1,0	0,1	0,0
1	(10,10,10)	(6,6,8)	(6,8,6)	(4,4,4)
0	(8,6,6)	(4,4,4)	(4,4,4)	(4,4,4)

To determine the internally and externally stable coalition, which puts itself in place, it is then a matter of determining the Nash equilibrium of this matrix game.

The great coalition (1,2,3) does not appear at the equilibrium. The coalition (1,2,3) corresponds to the triplet of decisions (*Yes*, *Yes*, *Yes*) of the three gasoline stations. A given station i (i = 1,2,3) belonging to the coalition (1,2,3) always has an incentive to deviate *unilaterally*: the best response of i to the *Yes* decision of other station is to change unilaterally its strategy (by announcing *No*). Using the concepts of internal external stability, the coalition (1,2,3) does not appear at the equilibrium from the fact that it is *internally* unstable.

With a similar reasoning, we can verify that all coalitions of size 2 (coalitions (1,2), (1,3) and (2,3)) are internally stable: no member of such a coalition has an incentive to exit unilaterally (and finally come back to the *status quo*). Such coalitions are also externally stable because the outside business never has an incentive to change its strategy to join the cartel. The cartels of size 2 are therefore stable. There is a multiplicity of equilibriums. Let us also observe that these sorts of cartels are equally profitable because their members obtain a higher profit in the cooperation than in the *status quo*: there is therefore no conflict between collective rationality and individual rationality[5].

5 Note that these particular cases where the unilateral deviation leads to a situation of *status quo*, the internal stability of the coalition guarantees the profitability of cooperation. It is not systematically the case when the coalition does not include more than two companies. The incompatibility between individual and collective rationality can then appear.

3.4.3.2. *Cartelization in a Cournot oligopoly*

Let us use the example, given in section 3.1, of oligopolistic competition in quantity between 3 firms. The three firms are identical and their marginal cost of production is null. The inverse demand is given by $P(Q) = Max(a - Q, 0)$, where $Q = q_1 + q_2 + q_3$ and $a > 0$. We have demonstrated that all two firms' cartels are non-profitable. In the two-stage adhesion game, a unilateral deviation of a cartel member in relation to its decision to adhere to this cartel tips the industrial structure toward the situation of *status quo*. For this reason, the concept of profitability of a two-firm cartel coincides with the concept of internal stability. Cartels of size 2 are therefore internally unstable.

Let us now study the total cartel understanding the set of companies.

The cartel maximizes $\pi_1 + \pi_2 + \pi_3$ in relation to variables q_1, q_2, q_3 by supposing that production is affected equally between members of the cartel ($q_1 = q_2 = q_3 = q$). We then obtain $\overline{\overline{q}} = \frac{a}{6}$, and the profit of its members is $\overline{\overline{\pi}}_1 = \overline{\overline{\pi}}_2 = \overline{\overline{\pi}}_3 = \frac{a^2}{4}$.

The Nash equilibrium in the situation of *status quo* leads to profits $\pi_i^* = \frac{a^2}{16}, i = 1,2,3$ and the profit of company 3 when it faces cartel (1,2) is given.

We can verify that the cartel is profitable but that it is not internally stable: each business of the cartel has an advantage to leaving the cartel unilaterally. There is therefore a collective incentive to form the total cartel but an individual incentive to leave unilaterally.

3.4.4. *The role of heterogeneities*

It is generally easier to treat the stability of coalitions in a symmetrical context of analysis where firms are identical (same characteristics of costs, size, marketed products, etc.). One of the consequences of this type of assumption is that the profits within the coalition are naturally identical at the outcome of the competition (e.g. at the equilibrium of the previous game in section 3.4.3). The same goes for the profits of the firms that stayed within the fringe. In a symmetrical frame, the profit levels of a member of the cartel and the fringe only depend on the size of the coalition and not the identity of its members.

In a symmetrical context, if a member of the fringe group is persuaded to join the cartel, the new cartel is *de facto* interiorly stable because no former member of the new cartel has any incentive to "take" the place of the entering firm in the fringe. Therefore, an externally unstable cartel, which puts together a new firm from the fringe, leads to a cartel that is necessarily internally stable (see [GIR 99] for the extensions of the concepts of stability in an asymmetrical context).

An asymmetrical frame requires a "one-by-one" approach of the flux between the cartel and the fringe. The incentive to join the cartel differs from one fringe's firm to another and the incentive to join the fringe can vary from one member of the cartel to another. In the case of an industrial competition, these incentives depend on the conditions of the offer of each of the producers (production costs, localizations of the firm and characteristics of offered products). The heterogeneities involve different levels of value created from the coalitions depending on the identity of the members and the identities of the players who remained on the fringe. The analysis is more complicated because it is necessary, when a firm assesses the difference in profits between fringe and cartel situations, to take into account that this difference depends on the size of the cartel as well as the identities of the firms in the cartel and in the fringe.

One example of the impact of firm heterogeneities is illustrated by the results obtained in the frame of an oligopolistic competition between non-identical firms, for example when the heterogeneity is reflected by differences in terms of production efficiency.

Consider three firms in competition over volume on a market. We suppose that firms 1 and 2 have identical production costs

$C_i(q) = \frac{q^2}{2}, i = 1,2$, whereas firm 3 has an eventually different cost given by $C_3(q) = \frac{cq^2}{2}, c > 0$. The inverse demand is given by $P(Q) = Max(a - Q, 0)$, where $Q = q_1 + q_2 + q_3$ and $a > 0$.

We assume that a cooperation project is launched. It consists, for the firms that wish to join in, of coordinating their strategies of produced quantities. The firms must simultaneously announce their participation or their refusal to participate. At the end of this stage, the firms that responded positively fix their production quotas cooperatively by maximizing their joint profit and acting as one single firm in the face of other firms (if there are any) that refused to cooperate. This confrontation leads to a Nash equilibrium in the second stage of the game.

The firms anticipate the profit they will obtain at the second stage of the game depending on the structure of the coalition that was formed at the first stage. The expected gains are given in Table 3.1. Table 3.1 shows the payoff matrix. These gains that are easily calculated are simply the Nash equilibrium profits associated with the coalition formed in the first step.

Individual profits / Coalition (or cartel)	π_1	π_2	π_3
Non-cooperative situation (status quo)	$\frac{3a^2(1+c)^2}{8(3+2c)^2}$	$\frac{3a^2(1+c)^2}{8(3+2c)^2}$	$\frac{3a^2(2+c)}{2(3+2c)^2}$
Cartel (1,2)	$\frac{5a^2(1+c)^2}{2(8+5c)^2}$	$\frac{5a^2(1+c)^2}{2(8+5c)^2}$	$\frac{9a^2(2+c)}{2(8+5c)^2}$
Cartel (1,3)	$\frac{2a^2c(2+3c)}{(5+8c)^2}$	$\frac{3(a+2ac)^2}{2(5+8c)^2}$	$\frac{2a^2c(2+3c)}{(5+8c)^2}$
Cartel (1,2,3)	$\frac{a^2c}{4+10c}$	$\frac{a^2c}{4+10c}$	$\frac{a^2}{4+10c}$

Table 3.1. *Potential cartels and associated payoffs*

We can then determine the stable and profitable cooperation of this game depending on parameter c. To obtain a more precise number, we give numerical values to the profits for values c = 1, 2, 6 by taking a = 10. This is equivalent to assuming in a first case (c = 1) that the firm 3 is identical to the others; in the second case (c = 2), it is moderately inefficient with respect to the others; and in the third case (c = 6), the firm is "very" inefficient in relation to its competitors.

Table 3.2 presents the gain matrix as well the conclusions as for the profitability and stability of different cooperation structures.

Coalitions/Cartels \ Individual profits		π_1	π_2	π_3	Profitability and stability of the coalition[6]
Statu quo 1,2,3	c=1	6	6	6	Undefined[7]
	c=2	6.88	6.88	4.08	Undefined
	c=6	8.16	8.16	5.33	Undefined
Cartel (1,2)	c=1	5.91	5.91	7.98	Externally stable and non-profitable (1,2)
	c=2	6.94	6.94	5.55	Internally stable, externally stable and profitable
	c=6	8.48	8.48	2.49	Internally stable, externally unstable and profitable
Cartel (1,3)	c=1	5.91	7.98	5.91	Internally unstable (1), externally stable and non-profitable (1,3)
	c=2	7.25	8.50	3.62	Internally stable, externally unstable and profitable
	c=6	8.54	9.02	1.42	Internally unstable, externally unstable and non-profitable (3)

6 In case of internal instability, we give in parentheses the firms that have incentive to deviate unilaterally. In case of external stability, the firm that has an interest to join the cartel is naturally the one that is outside the cartel (for cartels with two firms). In case of non-profitability we give in parentheses the members of the cartel for which the profit decrease compared to *status quo*.

7 By definition of cartelization, we analyze the stability of a cartel (and thus the viability of the strategic quantity associated with it) when the cartel comprises at least two firms. When a firm deviates from a cartel comprising 2 firms, the others members adjust their quantity in the second period of the game and the equilibrium of the second period is naturally the *status quo* situation.

Cartel (1,2,3)	c=1	7.14	7.14	7.14	Internally unstable (1,2,3) and profitable
	c=2	8.33	8.33	4.16	Internally unstable (1,2,3) and profitable
	c=6	9.37	9.37	1.56	Internally unstable (3) and non-profitable (3)

Table 3.2. *Stability of potential cartels for different firm typology (c = 1, 2, 6)*

3.4.5. *R&D in a context of asymmetrical firms*

Imagine that a strategic alliance project is launched by a firm among *N* present on the market. The cooperation project consists of taking on expenses necessary to obtaining a technological innovation considered crucial to the future of the industry. The alliance emerges at the end of a game in two stages. During the first stage, the firms announce freely and simultaneously their desire to join the project or not. The decisions being made, the alliance is set up and innovation is considered to be obtained for sure. The obtained innovation is, however, more or less important depending on the size of the formed coalition. A great coalition, as a result of the high financial capacity it can generate and the exchanges of information (technical in nature) that it can assemble, leads to a major innovation that a smaller coalition could not obtain. In the second stage of the game, firms face each other on the market (the ones that cooperated in the innovation process and the ones that did not). We suppose that the firms that decide not to cooperate in the first innovation process lead their own innovation project but are held back by insufficient funds and technical information. The competition takes place between three companies (that are independent when it comes to confronting one another on the market).

The possible coalitions that can emerge at the end of the game are (1,2), (1,3), (2,3), (1,2,3) and singleton coalitions (1), (2), (3). Singleton coalitions appear when two firms have refused to adhere to the cooperation.

We will call *status quo* the structure of coalitions that includes singleton coalitions. The appearance of singleton coalitions implies a return to the initial scenario where there exists no cooperation throughout the industry. The *status quo* leads businesses to the following profits:

$$\pi_1[1,2,3] = \pi_2[1,2,3)] = 1, \pi_3[1,2,3] = 8$$

To each possible coalition structure is associated a profit for each firm, which corresponds to the one it obtains at the second stage of the game, knowing that its performances on the market depend on its decision at the first stage, meaning the innovation it ends up with, the returns from the latter and the costs associated. These parameters vary depending on whether or not it has cooperated with other firms and depending on its initial capacity (financial and technological) to undertake innovation.

Note, $\pi_i[(S), N/S]$ is the profit of i when S is formed and *N/S* are independent.

The profits obtained depending on the structure of coalitions in place are given by:

$$\pi_1[(1,2,3)] = \pi_2[(1,2,3)] = 3, \pi_3[(1,2,3)] = 4$$
$$\pi_1[(1,(2,3)] = \pi_2[(1,3),2)] = 0, \pi_2[(1,(2,3)] = \pi_1[(1,3),2)] = 4, \pi_3[(1,(2,3)] = \pi_3[(1,3),2)] = 6$$
$$\pi_1[(1,2),3] = \pi_2[(1,2),3)] = 2, \pi_3[(1,2),3] = 6$$

In order to take their decision at the first stage of the game, the firms have to anticipate the profit associated with each of their decisions at the second stage of the game. The strategies played at this stage (*Yes* or *No* strategies) correspond to a Nash equilibrium for this stage, if that equilibrium exists.

We can give a matrix representation of the game by supposing, for example, that the line represents the decision of firm 1 and that the column represents the combinations of possible decisions for firms 2 and 3. The number 1 corresponds to the strategy Yes and 0 to No.

Decisions F2 and F3 Decision F1	1,1	1,0	0,1	0,0
1	(3,3,4)	(2,2,6)	(4,0,6)	(1,1,8)
0	(0,4,6)	(1,1,8)	(1,1,8)	(1,1,8)

To determine the internal and external stable coalition that emerges, we must identify the Nash equilibrium of this matrix game.

The great coalition (1,2,3) cannot be obtained at the equilibrium. The coalition (1,2,3) corresponds to the triplet of decisions (*Yes, Yes, Yes*) of the three firms. F1 and F2 have no incentive to deviate *unilaterally*: the best response by F1 to the decision *Yes* by F2 and F3 is to maintain the decision to participate (*Yes*) and not leave unilaterally (i.e. announce *No*). However, the same does not go for F3, which, knowing that (1,2) has been formed, has an interest in playing not *Yes*, but rather *No*, that is to deviate in order to obtain the profit of 6 in coalition (1,2,3) rather than 4. The great coalition cannot merge at the equilibrium. Using the concepts of internal and external stability, the coalition (1,2,3) does not emerge due to the fact that it is *interiorly* stable.

With a similar reasoning, we can verify that the coalition (1,3) is internally unstable, which is due to F3 that has an incentive to exit the coalition (and finally return to the *status quo*). The coalition (1,3) is also externally unstable due to the fact that F2 has an incentive to join it. Thus, coalition (1,3) cannot emerge at the equilibrium of the game. A symmetrical reasoning is applicable to the coalition (2,3) and leads to the same instability result.

The only coalition that is internally and externally stable is the coalition (1,2). None of its members have an incentive to unilaterally change strategy in order to join F3 and additionally, F3 has no reason to join the coalition (1,2).

Let us observe that the cartel (1,2) is also profitable because both companies F1 and F2 obtain a higher profit in the cooperation than in the *status quo*: there is therefore no conflict between collective and individual rationality.

3.5. Conclusion

The formation of coalitions is a process that is generally quite hard to formalize. We have used an array of examples to try and give an idea of the conceptual richness and the possibilities of application of a basic concept of this theory (the concept of internal and external stability). We have discussed a number of issues linked with the formation of coalitions inspired by real situations involving firms, and, in some cases, public authorities, in various sectors of activity.

Many economic studies have shown how these concepts can be useful for understanding the subtle mechanisms that result from complex strategic interactions, which are amplified by the existence of multiform effects on the formation of a coalition: externalities on the rest of the players depending on the formed coalition and vice-versa (i.e. the effect of others on the coalition), created value depending on the size of the coalition but also on the characteristics of its members, etc.

The usefulness of these concepts has been evidenced by a number of studies touching on various sector problems. Take, for example, the agri-food sector in which coalitions of firms (retailers, agri-food companies, etc.) have to coordinate themselves in order to set food safety standards [GIR 12], in the field of the economy of the environment, with the emergence of environmental agreements associating a partial number of countries or all of them together [GRA 14]. There are also studies on cooperation procedures in R&D by relying on this conceptual frame or by proposing extensions to take into account the possibility of a veto right for the members of a coalition to its extension. The proposed study by [BAL 00] offers an unexpected use of the concept of stability in the field of human resources management, where the idea is to identify incentives that create loyalty among qualified employees in one company against poaching from competitors. A coalition is then no longer a group of companies (as is tradition in economics) but a group of employees deciding to remain in the mother company (see also [ABE 99] for a novel use of this concept). Examples for management and economics applications of the concept of internal and external stability or other concepts of coalition forming theory are plenty and the list of possible applications is certainly not closed. There are still a multitude of questions and fields to explore where the context of inter-player interactions can give an insight into a rich and productive use of this theory.

4

Application 1: Dieselgate

4.1. Introduction[1]

The Volkswagen (VW) case in 2015, analyzed by [BAR 15] and [CAV 16], highlighted a new industrial strategy adopted by car manufacturers to escape official environmental emission standards. Such maneuvers circumvent regulations and have always existed, in particular in the food industry, with the example of Chinese milk contaminated with melanin: though this case, which rocked the industry (Box 4.1), revealed that these strategies could be quite sophisticated and involved a circumvention process combined with advanced technology.

> VW is not the only manufacturer to have been accused of "fixing its engines". In May 2016, the motor group Mitsubishi Motors faced a media storm after it was revealed that it used fraudulent means to falsify the energy performances of some of its vehicles. It would appear that this was not something new. "The Japanese manufacturer admitted that since 1991 it has been using an illegal method to present fuel consumption levels to be better than they really are. According to the financial newspaper *Nikkei*, *'dozens'* of models are implicated"*. In late 2016, it was Renault's turn in the spotlight. The French manufacturer is said to have lied about the effective emission levels of its diesel engines, which in fact were above legal levels in terms of carbon dioxide (CO_2) and nitrous oxide (NO_x). A number of journalistic sources (including French newspaper *Libération*) cited a document

1 The factual elements taken into account in this chapter are correct prior to the end of August 2017, the date of the analysis proposed in this chapter.

Game Theory Approach to Managerial Strategies and Value Creation,
First Edition. Abdelhakim Hammoudi and Nabyla Daidj.

from the *Direction générale de la concurrence, de la consommation et de la répression des fraudes* (DGCCRF)[2], which was communicated to the courthouse**. *Libération* wrote that this 39-page-long document written in November 2016 concluded, after weeks of investigation, that "Renault SAS deceived consumers on the controls performed and in particular the regulatory control of emission compliances […]". "The firm used a strategy that aimed to falsify the results of antipollution tests".

*http://www.lemonde.fr/automobile/article/2016/05/18/le-patron-de-mitsubishi-motors-demissionne-apres-un-scandale-de-fraude_4921486_1654940.html#m7S9qgIztmqIlD3G.99.

**https://www.challenges.fr/finance-et-marche/renault-suspecte-d-avoir-trompe-ses-clients-sur-le-diesel_460493.

Box 4.1. *"Dieselgate", or the multiplication of fraud cases in the car industry*

The primary question that arises in the VW case can be formulated as follows: "Should I implement a process for circumventing the compliance controls by public authorities?" Moreover, what are the conditions that can create strategic incentives that lead to resorting to such processes?

4.2. Storytelling: for those who missed the beginning

In 2014, the European giant VW was the second largest[3] car manufacturer, with 10.14 million cars sold worldwide. Researchers at the University of West Virginia, commissioned by the ICCT[4], realized after a number of tests that VW vehicles were emitting up to 40 times more levels of oxide than permissible. VW was forced to admit this was the case and judged that this was due to technical problems and unexpected conditions of use. During the first semester of 2015, VW became the leading global manufacturer ahead of Toyota with 5.04 million cars sold against 5.02 million cars by its nearest competitor. In

2 General department of competition, consumption and anti-fraud.

3 Number one is Toyota with 10.2 million cars sold in 2014.

4 International Council on Clean Transportation (ICCT) is an independent NGO that performs scientific analyses and research into environmental regulations.

July 2015, the German manufacturer recognized the existence of technology that could falsify emission results, though it did not give any information as to its use. In early September, VW recognized the firm’s use of fraudulent software. This is how on September 18, the scandal emerged with a statement by the EPA (*Environmental Protection Agency*), publicly accusing VW of fitting a number of its cars in the United States with a fraudulent device.

What were the incentives that pushed VW to use this fraudulent software? The challenge for VW since 2005 has been to increase its market shares in the United States by developing a diesel engine that responds to emission regulations that are harsher in the United States than in Europe. Complying with these standards is possible using a device based on SCR (Selective Catalytic Reduction) technology that neutralizes nitrous emissions and can cost up to 300 euros per vehicle. VW then decided to minimize that cost by researching a simpler device that would manipulate the control tests. It equipped 11 million vehicles with the fraudulent software supplied by Bosch for internal use. This program allowed them to falsify the results of emission tests for diesel engines during control tests, in normal driving conditions, where vehicles emit over 40 times more pollutants (oxide and nitrous) than when at a standstill [CAV 16]. After the trick was discovered, VW had to bear the financial consequences and decided to reduce its research budget by 1 billion euro due to how much it was costing them to recall the 11 million vehicles impacted. The cost rose to 6.5 billion dollars and the fines were in the range of 16 billion dollars [GEO 16].

This manipulation process generated large costs because it was associated with a more or less sophisticated procedure involving a minimum of R&D. Is the decision to take action justified by the fact that implementation costs will be comparatively lower to the ones that would be involved for a compliance process? Are there other considerations that can vary or favor this deceit? We attempt to use game theory to explain how an operator can make this sort of decision as a result of strategic analysis.

4.3. Presentation of the facts and strategic reading[5]

Consider a firm, a car manufacturer, for instance, with a production capacity of *N* products (in this case *N* vehicles produced and sold over study period). The firm is active on a regulated market that applies environmental standards such as emission regulations. This standard is assumed to be a level of pollution $\bar{q} \in [0,1]$. This means that the standard gets more and more severe as $\bar{q}$ approaches 0. The regulatory body possesses a control or certification system that allows it to identify any non-conforming product and prevents it from being commercialized. This control is supposed to be characterized by a parameter $(\theta, \theta \in [\,\theta_{\min}, 1]\,, \theta_{\min} > 0)$ that measures the sophistication of the homologation test or its technical resistance to fraudulent attempts. $\theta_{\min}$ refers to the lowest level of sophistication that serves to identify breaches of regulation when the firm is passive, in the sense that it does not attempt to circumvent it with deceitful techniques (e.g. by fitting its vehicles with fraudulent software). The choice of a level of sophistication of the control process and eventually its level of efficiency require more or less high costs for the public authority. We note C_θ as one such cost function for the public authority.

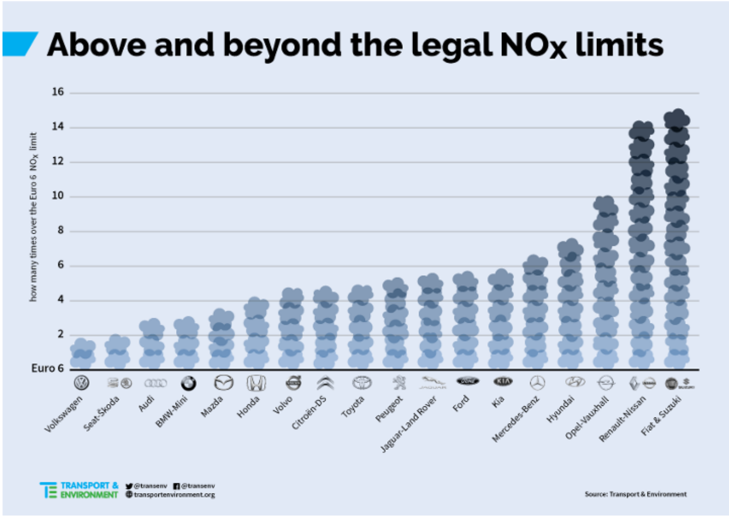
Let us first ask: what does a fraudulent action consist of in this context? The answer, of course, is for the firm to build cars whose engines emit more gas than is allowed. But the fraudulent strategy must be further refined: the firm must, if it has the technological ability to do so, master or control the intensity of the fraud by determining the differential emissions in relation to the standard (or the breach level of the standard). Investigations into the Dieselgate case confirmed this fact by demonstrating that all companies do not have the same levels when it comes to breaching the standard (Box 4.1). The firm must also decide on the number of vehicles that will be equipped with the non-compliant device (defeat software). A strategic trick involving the standard involves a combination of these two

5 The conceptual analysis proposed in this chapter is from an ongoing research article [NAI 18]. The translation of the primary elements of modelization proposed in the article in a more accessible conceptual frame (game theory) is from a lecture by Hammoudi to Master's level students.

decisions: a "pollution" level to be assigned to non-compliant cars and a number of vehicles that will carry this technology.

The French journal *Science et avenir*, in its September 20, 2016 issue, gave a detailed account of the heterogeneousness of the breaches by the brands and companies involved. OGN Transport & Environment collected the measures of nitrous oxide (NOx) emissions of approximately 230 models of diesel cars in France, Great Britain and Germany. The results are disastrous for all car manufacturers.

All manufacturers are affected by the breach of pollutant emissions, states the report by the aforementioned NGO, and concerning vehicles, Volkswagen is the one that has the most respect for the standards. In France, 5.5 million new diesel vehicles are thought to be above the emission standards Euro5 and Euro6 in terms of NOx (nitrous oxide) set during the tests. T&E calculate that there are 29 million diesel cars in Europe:



On the *x* axis, the graph presents the tested brands. The *y* axis presents the number of times the brands breached the Euro6 levels of NOx (nitrous oxide), according to the NGO Transport & Environment.

Box 4.2. *Diversity of emission breach levels in the Dieselgate case*

To structure the strategic consideration and explain the arbitration faced by companies between cheating and not cheating, we present different elements that naturally help this decision:

– *The level of the environmental standard (maximum authorized emissions threshold)*. This standard, which we note as $\bar{q}$, can be more or less severe (severe if close to 0).

– *The pollution level of cars that do not respect the standard*. We state q_e as the level of pollution of these cars and n as the number of cars manufactured by the firm that will use this system. The higher this level, the more the vehicle pollutes and becomes noxious for both the environment and the health of the population.

– *The differential in gas emissions between compliant and non-compliant cars*. This difference, which we note as $q = q_e - \bar{q}$, is the amplitude of the breach of non-compliant cars.

– *The degree of efficiency of compliance tests*. The level of efficiency of compliance tests is a choice made by the authorities before the firm intervenes in the game. We can therefore consider that if the public decision (choice θ) is taken rationally, the public authority must take into account (on condition that it has the ability to) the influence this decision has on the incentives for companies to cheat. The efficiency of compliance tests, in other words, the "resistance" of tests to technological cheating procedures, is a strategic variable of public authorities. It does, however, incur a cost that we note as $H(\theta)$: marginally increasing the efficiency of compliance tests, generating an additional cost tied to the research and innovation it requires.

– *The cost of research/innovation and setup of the circumvention procedure*. The circumvention procedure needs to continue being more and more sophisticated as the compliance test becomes infallible. The cost of research/innovation associated with circumvention procedures increases with the efficiency of public compliance. The level of quality or efficiency of public compliance procedures is supposedly known by companies.

– *The probability of suspicions that arise and lead to a formal investigation*. In analyzing the VW case, it appears that identifying the fraud can occur as a result of a suspicion or a denunciation (by an NGO, for example), leading to an investigation, which in turn leads to more in-depth control tests than compliance tests used by public authorities. These in-depth controls conclude a period of suspicion and can be contracted to third parties that have more effective control methods that go beyond anything that the authorities could perform. When the investigation is launched, any fraud that has taken place is identified every time: the exceptional controls performed in the event of an inquiry are considered to be perfect. We set Φ the probability for any such investigation to arise. To make a rational decision (fraudulent or not), the business takes Φ into consideration.

Other factors can, however, influence this decision to commit fraud. Among these factors, we cite the following two elements:

1) *Fines and other payouts in the event of fraud being detected*. The fine set by the public authority to sanction the fraud must be clear in order to be taken into account in the strategic calculation of the firm when it is attempting to make a decision (fraudulent or not). We note R as the amount of the fine. The fine R can be a set amount or indexed on the severity of the fraud (how big the breach of the authorized level of pollution is and number of vehicles involved). The payouts are also anticipated by the firm. They can result from legal sanctions, consumer rights claims and a minimum damage can be set in advance by the firm (Box 4.2). Even if part of this compensation is not known beforehand by the firm, it must estimate it in order to make a decision. The fine and compensation form a total cost which we call $C(q, n, R)$.

2) *The industrial structure and degree of competition in the sector*. A more or less strong competition can have an effect on a firm's incentives to research non-regulatory means to acquire profits. The initial intensity of competition measured by the degree of concentration of the market or a leadership vacuum can lead companies to consider fraud.

As highlighted previously, to deceive public homologation tests, which comes down to making these tests ineffective, involves a research commitment (R&D, for example) or the purchase of one such process from a third party. The process is all the more sophisticated, meaning it will trick efficient control tests, the more R&D effort that goes into it (or the purchase cost from a third party) agreed to by the firm. We write γ as the level of technical sophistication of the circumvention process, γ ranging from 0 to 1 ($\gamma \in [0,1]$): the closer γ is to 1, the more sophisticated and expensive the process is. We assume that the cost of acquisition (or R&D) of a process of sophistication γ is given by a function C_γ.

In its summary of the Dieselgate case, the newspaper *Libération* wrote: "According to our friends over at Le Monde who had access to a transcript from the investigators with the *Direction générale de la concurrence, de la consommation et de la répression des fraudes* (DGCCRF), the 12-brand group (VW, Audi, Porsche, Skoda, Seat, etc.) risks, in France alone, of a fine that could reach 19.73 billion euros, which is almost as much as in the US, where it has already paid 22.6 billion to face the lawsuit, after negotiations with the federal justice department. Volkswagen is suspected of having used a cheat-software to pass the control tests and trick testers into believing their engines were within regulations in terms of pollution emissions; and this fraud involved 11 million diesel vehicles sold worldwide, as admitted by the group. In France, nearly 1 million VW, Audi, Seat or Skoda vehicles were involved in the scandal. The maximum amount for the fine the German group could be looking at in France – almost 20 billion – was calculated by the DGCCRF on the basis of the years 2012, 2013 and 2014. It corresponds to a financial sanction representing 10% of the VW group's earnings in France over the three years in question. In comparison, as was revealed by *Libération*, Renault is risking a fine of 3.58 billion euros for duping customers on the reality of diesel emissions".

Source: http://www.liberation.fr/futurs/2017/05/23/dieselgate-la-justice-francaise-pourrait-reclamer-20-milliards-d-euros-a-volkswagen_1571655.

Box 4.3. *Fines incurred in the Dieselgate case [FER 17]*

The sophistication of homologation tests will, of course, influence the behavior of the firm, meaning the choice of level of efficiency of γ selected by the firm if it considers committing fraud. If the firm opts to circumvent control tests by implementing a process γ adjusted at θ (or, more formally decides $\gamma(\theta)$), it remains to anticipate the fines and other costs it will have to pay in case of suspicion and in-depth investigation. It is the levels of (q, n) that determine in part the risk that a suspicion may arise amplified to the point where it causes the investigation and the identification. The suspicion can, for example, develop depending on whether the levels of q and n are high or low: an exaggeration in the levels of emissions and an important number of vehicles involved in the fraud can easily create doubt and suspicion.

However, neither variable q nor n can alone explain the probability of an investigation. This sort of probability is higher in societies where there are powerful NGOs that survey consumer health and environmental responsibility. By deciding to lead an investigation or sub-contract it to a third party, public authorities often respond to information or pressure from NGOs. Subsequently, the probability of an investigation taking place (and for the fraud to be discovered) is due to endogenous causes (decisions q and n of the firm) and an exogenous cause (the efficiency of existing NGOs). We can therefore formally conclude that $\Phi \equiv \Phi(q, n, v)$, where v, $(v \in [0,1])$, is an indicator of effectiveness and dynamism of present NGOs. The closer v is to 1, the more powerful, efficient and vigilant the NGOs are.

Let us also state that such a probability also involves an important problem that we will not answer here: is it more likely that an investigation will be launched (or raise suspicion) for a fraud involving a large number of cars emitting little unauthorized pollution or for a fraud involving few highly polluting cars? The answer to this question, which is one of the defining elements of probability $\Phi(q, n, v)$, will of course play an important role in the emergence of the strategic creation of the firm (q, n, γ).

4.4. The strategic variables and the associated game

To structure strategic thinking, we utilize the tools of game theory presented in the previous chapters. We outline the game and its rules that could represent a basis for relevant discussion of interactions pertaining to textbook cases.

First, there are two players involved: the public authority and the firm. The public authority must simultaneously choose:

– a technological process for performing the control tests, which corresponds to choosing θ, ($\theta \in [\,\theta_{\min}, 1]$);

– a standard $\bar{q}$;

– a fine R that the firm must pay if it is found guilty of fraud.

A strategy of the public authority is therefore the combination of three actions $(\theta, \bar{q}, R\,)$ taken within a *strategic space* $[\,\theta_{\min}, 1]X[0,1]X[0, +\infty]$.

Let us state again that a public process θ is associated with a degree of efficiency and can therefore make it more or less difficult (meaning more or less costly) depending on its proximity to 1, for a firm to implement a circumvention process.

The firm must decide to standardize or not standardize its vehicles, and whether or not to commit fraud. As we have seen previously, this “cheating” strategy in reality hides the following three simultaneous actions:

– the choice of a circumvention process of the control tests;

– the choice of the number of vehicles to be equipped with the fraudulent system;

– the level of emissions of the vehicles equipped with the fraudulent system (difference between these cars’ pollution levels and the regulatory threshold).

4.4.1. *The rules of the game*

Actors clearly act sequentially.

– Stage 1. The public authority simultaneously chooses the efficiency $\theta \in [\,\theta_{\min}, 1]$ of its control test, a maximum threshold $\bar{q}$ authorized in gas emissions and the fine R.

– Stage 2. The firm decides on one of the two following options:

i) Not to cheat, in which case it fits all of its vehicles with a system emitting a level of pollution q_e inferior or equal to $\bar{q}$.

ii) It decides to cheat, in which case it decides simultaneously on three actions:

– a circumvention process of public controls of a level of sophistication γ, (γ ∈ [0,1]);

– a breach level of gas emissions in relation to the standard $(q > 0)$;

– a number n of vehicles to be equipped with fraudulent systems (engines characterized by $q > 0$).

When the firm has decided to cheat, two events can occur with probabilities that the firm should be able to predict:

– a situation where no suspicion impedes the firm's strategy and it manages to sell all of its standard and non-standard fraudulent vehicles and makes profit from them;

– a situation where suspicions arise and lead to an investigation that uncovers the fraud. The firm must pay a fine, compensation to wronged consumers and inherent costs of recalling sold cars, making them respond to regulations.

The game presented previously has perfect and complete information.

Figure 4.1 represents this game.

Now that the stage is set, let us give a summary of the different parameters and variables of the model (there are a number of them) and their strategic impacts. There are three types of variables: variables connected to public decision (Table 4.1), variables connected to the firm decision (Table 4.2), the exogenous parameter v and the function $\Phi(q, n, v)$, which, at the equilibrium, emerges from the interaction of *all* exogenous variables that determine the formation of gains of both players (Table 4.3).

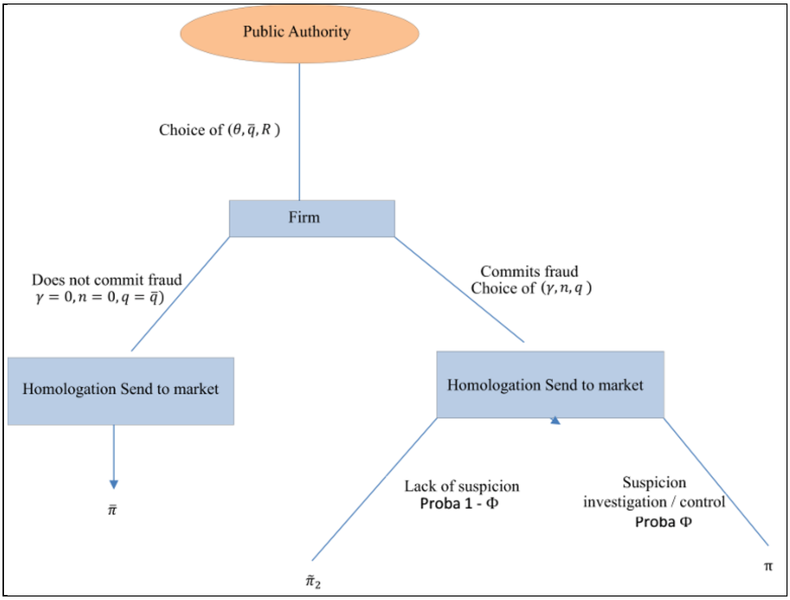


Figure 4.1. *The different stages of the game*

Table 4.1 describes the triplet of decision $(\theta, \bar{q}, R)$ variables by public authorities and their effects.

Parameters/ strategic variables	Definition	Strategic effects >0	Negative effects
θ	Level of efficiency of the public control procedure	Makes public control tests more efficient, deters companies from committing fraud, can push companies to require more R&D for circumventing the controls	Induces a public cost in proportion to the selected level of efficiency
$\bar{q}$	Level of the standard set by public authorities	A positive effect on the health and the environment as $\bar{q}$ approaches 0	As $\bar{q}$ approaches 0, the standard becomes more severe and impacts costs negatively for the firm. It can tempt companies into cheating
R	R: fine in the event the fraud is uncovered during an exceptional control	Deters fraud	Public costs generally low

Table 4.1. *Strategic decisions by public authorities*

Table 4.2 describes the triplet decision variables (γ, n, q) by the firm.

Parameters/strategic variables	Definition	Strategic effects >0	Negative effects
γ	Level of efficiency of the firm's cheating process for duping public authorities	Makes control tests ineffective	Creates an increasing cost depending on the efficiency of the device
n	Number of vehicles equipped with the defeat device	For a set level of pollution for each vehicle, as n increases, the firm saves more and more money in conforming costs. Allows a firm to be more competitive and acquire market shares from its competitors	As n increases, the probability of causing an investigation and being discovered increases
q	Pollution differential with the standard (characteristic of non-regulation vehicles fitted with the defeat device)	Savings on the cost of each vehicle equipped with the deceptive device. Savings increase with q	When q increases, the probability Φ of an investigation can increase and lead to the fraud being uncovered

Table 4.2. *Strategic variables of the firm*

Table 4.3 describes the effect of the variable v and of the probability $\Phi \equiv \Phi(q, n, v)$ product of the actions of public authorities and firm at equilibrium.

Parameters/ strategic variables	Definition	Strategic effects >0	Negative effects
v	Indication of efficiency of NGOs	When v increases, the vigilance of NGOs increases and the probability of an investigation being launched increases. Favorable for fraud deterrence	
$\Phi \equiv \Phi(q, n, v)$	Probability for an investigation to arise	Increases deterrence toward fraud. An increase of n and q means an increase in the probability for an investigation to be launched	

Table 4.3. *Exogenous index of NGO quality and probability resulting from firm/NGO interactions*

For each possible value of $(\theta, \bar{q}, R)$, public authorities must anticipate the strategy (q, n, γ) that the firm will use as a (best) reaction to $(\theta, \bar{q}, R)$. To decide on its response to $(\theta, \bar{q}, R)$, the firm must anticipate the effect of each combination $(\theta, \bar{q}, R)$ and (q, n, γ) over its profit. This profit is an expected profit as it depends among other things on the probability $\Phi(q, n)$ of being identified as a result of an investigation. If such an event were to occur and the fraud were to be identified, the firm would pay the total cost $C(q, n, R)$. If no investigation is launched, with the probability (1-$\Phi(q, n, v)$), it recovers a relatively high profit because of the sales of its unregulated cars on which it saved on conforming costs and on its regulatory vehicles.

The relation between the public authority, which must find more and more efficient control tests, and companies that choose to find more and more sophisticated ways to trick them is reminiscent of the never-ending story between the owner of a "robbable" home and a burglar: the former does its best to refine the locks and the latter to find a way to break through them. Can we take this reasoning further and find analogies in strategic behaviors in these two stories? How far can this race for innovation between the burglar and the homeowner go? The homeowner can give up first if the sophistication of the locks he or she is using ends up being too costly in comparison to what he or she is supposed to be protecting (value of his or her possessions). He or she can therefore stop the race and use a reasonably sophisticated lock. But in doing so, he or she is not necessarily going to get burgled. He or she can count on (1) the burglar's common sense who will himself or herself find that the new process of breaking in past the lock is too costly in comparison with the value of the spoils of the robbery, and/or (2) that the probability of being caught by the police after the burglary is high enough considering, for example, the efficiency and the progress accomplished by the police in this area. Subsequently, the progress made by the police will allow the homeowner to not constantly outbid the robber, to reduce his or her lock cost and deter the burglar from even attempting a burglary.

Box 4.4. *The burglar and the homeowner*

Acting as leader in the sequential game, public authorities can, by selecting a level of sophistication of control tests, orient and influence the firm's decision by making the fraud more or less costly. A highly sophisticated control test decided on in the first stage can, for instance, force the firm to abandon the idea of searching for a circumvention method due to the acquisition or innovation cost such a method would present. As the public authority plays first, what immediately comes to mind is: will the public authority select a relatively sophisticated process to deter illegal behavior? This question is actually revealing the complexity of this sort of game because the answer depends, as we will see later, on the public authorities' decision criterion; in other words, its gain. As we will see, depending on the criterion of collective good it sets for itself, it will not systematically have an incentive to deter such a behavior.

4.4.2. *Payoff*

Suppose that the firm wishes to equip n of its vehicles (out of N) with a fraudulent engine. The expected profit by the firm is divided into two parts: a profit obtained from the sale of non-fraudulent vehicles, which we call its "competition" profit, in reference to its share of "honest" gains, and a profit obtained from the sale of the n fraudulent vehicles.

We note $\bar{\pi}\,(N-n,\bar{q})$ as the competition profit obtained without cheating on $N-n$ vehicles in the range. If the firm decides to respect the standard on all of its vehicles, it then obtains a profit of $\bar{\pi}\,(N,\bar{q})$. We will call this profit the *status*-*quo* profit.

We can consider that the level $\bar{\pi}\,(N-n,\bar{q})$ is an indicator of the level of competition in the sector. This profit can be independent of the fraud performed on the range $N-n$ or be (positively) impacted by it. The fraud can indeed help the firm be more competitive and acquire market shares from its competitors. Thus, the fraud can have a positive effect, not only on the "illegal" part of its profit but also on its "legal" part. We assume that the firm can perfectly evaluate that profit $\bar{\pi}\,(N-n,\bar{q})$.

The firm's total expected profit is:

$$\pi(\theta,\bar{q},n,q,\gamma) = \bar{\pi}\,(N-n,\bar{q}) + \tilde{\pi}(\theta,\bar{q},n,q,\gamma)$$

where $\tilde{\pi}(\theta,\bar{q},n,q,\gamma)$ is the expected profit from the fraud.

Taking into account the previously defined variables, this profit is written as:

$$\tilde{\pi}(\theta,\bar{q},n,q,\gamma) = \tilde{\pi}_2(\theta,\bar{q},n,q,\gamma) - \phi(q,n,v)C(q,n,R)$$

where $\tilde{\pi}_2(\theta,\bar{q},n,q,\gamma)$ is the profit obtained from the sale of non-regulatory vehicles. It incorporates the cost C_γ tied to the research and implementation of the circumvention process of level γ. When an investigation is launched and the fraud is identified (with a probability $\phi(q,n,v)$), the firm obtains this profit from which we deduct the total cost (fines, compensations, vehicle recalls, etc.) it must pay.

In the end, the total expected profit of the firm is written as:

$$\pi(\theta,\bar{q},n,q,\gamma) = \bar{\pi}\,(N-n,\bar{q}) + \tilde{\pi}_2(\theta,\bar{q},n,q,\gamma)$$
$$-\phi(q,n,v)C(q,n,R)$$

Public authorities must also set their decision criteria. First, such a criterion must account for the effect of pollution on the environment and the health of the population. The pollution emitted is associated with the firm's vehicles and is written as $Q(n,q,\bar{q}) = nq + (N-n)\bar{q}$. To simplify, we assume that the public authority has the possibility to attribute to each level of total pollution an estimate of the monetary health cost, which we write as $C_S[Q(n,q,\bar{q})] \equiv C_S(n,q,\bar{q})$.

The public decision criterion must also incorporate the cost associated with the control test implemented, which depends on the level of sophistication selected to prevent the fraud.

Let us suppose simply that the decision from the public authority is the following function, which it proposes to minimize:

$$W(n,q,\bar{q},\theta) = C_S(n,q,\bar{q}) + H(\theta)$$

$H(\theta)$ is the cost of the control test.

This criterion does not include other surplus that public authorities could very well consider in a micro-economic perspective and a utilitarian approach: money received by the public authority in the event that the fraud is identified and profit and consumer surplus.

4.5. Game resolution and strategic analysis

The solution to the game whose simple representation is summarized in Figure 4.1 is determined by the backward induction process. The public authority anticipates the best reaction by the firm to its strategy. We are therefore placing ourselves at the last stage of the game. At a strategy $(\theta, \bar{q}, R)$ decided by authorities at the first stage of the game, the firm must determine which is the best profit it could obtain if it were to cheat (and therefore with which response (n,q) to $(\theta, \bar{q}, R)$). It then compares that profit to the one it could achieve by conforming to regulation on all of its vehicles. If it is higher, it commits fraud. Otherwise it does not.

More formally, for a given $(\theta, \bar{q}, R)$, the firm wants to determine $[n(\theta, \bar{q}, R), q(\theta, \bar{q}, R), \gamma(\theta)]$, which maximizes its profit. The strategy $[n(\theta, \bar{q}, R), q(\theta, \bar{q}, R), \gamma(\theta)]$ is therefore the best response to the strategy $(\theta, \bar{q}, R)$ played by the authorities.

Note $MR_E(\theta, \bar{q}, R) = [n(\theta, \bar{q}, R), q(\theta, \bar{q}, R), \gamma(\theta)]$; this is the best response by the firm (indexed by E) to strategy $(\theta, \bar{q}, R)$ by public authorities.

The profit from fraud obtained when the firm applies this best response is then simply written as $\tilde{\pi}[\theta, \bar{q}, n(\theta, \bar{q}, R), q(\theta, \bar{q}, R), \gamma(\theta, \bar{q}, R)]$, which appears as follows:

$$\tilde{\pi}_2[\theta, \bar{q}, MR_E(\theta, \bar{q}, R)]$$
$$-\phi[\theta, \bar{q}, n(\theta, \bar{q}, R), q(\theta, \bar{q}, R), \gamma(\theta)] \,.\, C[q(\theta, \bar{q}, R), n(\theta, \bar{q}, R), R]$$

The firm must compare the *total* profit $\pi(\theta, \bar{q}, n, q, \gamma)$ to $\bar{\pi} \equiv \bar{\pi}\,(N, \bar{q})$, the profit obtained by not cheating on any vehicle. It must then assess the sign of the difference:

$$\Delta = \bar{\pi}\,(N - n, \bar{q}) + \tilde{\pi}[\theta, \bar{q}, n(\theta, \bar{q}, R), q(\theta, \bar{q}, R), \gamma(\theta)] - \bar{\pi}\,(N, \bar{q})$$

$\bar{\pi}\,(N, \bar{q})$ is the *status-quo* profit.

If this difference is positive, the firm will decide to cheat; if not, it will conform to the standard established for all of its vehicles.

The public authority goes first, anticipating the best response from the firm to its strategy and the consequences of the set of decisions based on the sign of this decision. The public authority must integrate this information ($MR_E(\theta, \bar{q}, R)$ and the firm's final decision, namely the sign Δ) in the expression $W(n, q, \bar{q}, \theta)$ of its decision criterion. It then obtains a welfare criterion depending exclusively on its strategy and not the firm's, because the latter has already been internalized via $MR_E(\theta, \bar{q}, R)$. Therefore, the criterion which it must minimize depends only on its own actions and is written as:

$$W(\bar{q}, \theta, R) \equiv W[n(\theta, \bar{q}, R), q(\theta, \bar{q}, R), \bar{q}, \theta]$$

The authorities must then determine at the first stage the levels of θ, $\bar{q}$ and R that minimize $(\bar{q}, \theta, R) = C_S[n(\theta, \bar{q}, R), q(\theta, \bar{q}, R), \bar{q}] + H(\theta)$.

We see that as the public authority plays first, it can eventually influence the action played by a firm at the second stage, meaning on the level of three components of $MR_E(\theta, \bar{q}, R)$, that is the triplet of responses $[n(\theta, \bar{q}, R), q(\theta, \bar{q}, R), \gamma(\theta)]$ and *in fine* on the difference $\Delta = \tilde{\pi}[\theta, \bar{q}, n(\theta, \bar{q}, R), q(\theta, \bar{q}, R), \gamma(\theta)] - \bar{\pi}\,(N, \bar{q})$, making this difference positive or negative.

It can, for example, orient the firm toward a choice ($MR_E(\theta, \bar{q}, R)$), which would lead to a negative difference Δ, meaning a fraud deterrence. But does the public authority always have an incentive to play such a strategy?

We present here two solution scenarios to the game, meaning two possible equilibrium situations, and we show for each of them which reality and specificity it can cover.

4.5.1. *Perfect equilibrium of the game where fraud is deterred*

This case corresponds to the situation where the public authority sets a standard at level $\bar{q}$, implements a sufficiently reliable control test and a penalty in case of fraud so that the firm cannot find an incentive to commit such an act. Finding this triplet of deterring actions in regard to fraud is not sufficient. For it to be applied and be a perfect equilibrium of the game (that is to say the optimal firm's strategy to meet the standard at the second stage), this set of solutions must be the one that minimizes the decision criterion of the public authority. There cannot be other sets of solutions that ensure a lower public cost W. In particular, there cannot be another set of solutions that does not deter fraud and generates a lower public cost. This is not always guaranteed.

First, let us deconstruct the mechanisms that allow, via the strategic levers $\theta, \bar{q}$, and R, to deter fraud and analyze how they can combine to ensure such a solution at the second stage of the game. To structure the thought, let us set $\bar{q}$ and R and assess how the "efficiency of the control test" lever must adjust to deter fraud.

For such a solution to be possible, the public authority must choose a θ that is sufficiently close to 1 for a given $\bar{q}$ and R. Its proximity to 1 depends on the values of $\bar{q}$ and R.

By choosing a level of efficiency of the control test, the public authority puts the firm in a situation where it will not find it advantageous to implement a circumvention process for this control test. In other words, with such a level of θ, any technical circumvention process considered by the firm will cost it so much that no matter the level of breach considered for the vehicles to be fitted with the illegal system, we obtain:

$$\Delta = \bar{\pi}\,(N-n,\bar{q}) + \tilde{\pi}[\theta,\bar{q},n(\theta,\bar{q},R),q(\theta,\bar{q},R)\gamma(\theta)] - \bar{\pi}\,(N,\bar{q}) < 0$$

Let us restate that $\tilde{\pi}[\theta, \bar{q}, n(\theta, \bar{q}, R), q(\theta, \bar{q}, R), \gamma(\theta)]$ is written as:

$$\tilde{\pi}_2[\theta, \bar{q}, n(\theta, \bar{q}, R), q(\theta, \bar{q}, R), \gamma(\theta)]$$
$$- \phi[\theta, \bar{q}, n(\theta, \bar{q}, R), q(\theta, \bar{q}, R), v] \,.\, C[q(\theta, \bar{q}, R), n(\theta, \bar{q}, R), R]$$

The implementation cost of a circumvention process will therefore influence the first part of this profit, meaning $\tilde{\pi}_2[\theta, \bar{q}, n(\theta, \bar{q}, R), q(\theta, \bar{q}, R), \gamma(\theta)]$, throughout the cost C_γ incorporated in this profit, and associated with the level of efficiency $\gamma(\theta)$ necessary to make the control test of level θ ineffective.

We can see that part $\tilde{\pi}_2\,(.)$ of this profit can decrease with a θ, which is increasingly closer to 1 and the second part can increase granted that $\phi(.)$ and/or $C(.)$ increase. In other words, a sufficiently sophisticated homologation test and/or effective NGOs and/or large fines will naturally deter companies from committing fraud at the second stage of the game.

Note that the public authority can have deterrence capabilities but through the implementation of a homologation test that is too costly for society. Deterrence can thus benefit consumer health but it is too costly to be implemented by public authorities. In this case, the public authority will give up on implementing this sort of process and fraud will be present at the perfect equilibrium of the game. This result can appear slightly shocking in the sense that we can end up sacrificing consumer health as well as the environment due to a high deterrence cost. Everything is of course tied to the decision criterion chosen by the public authority: it can decide to adjust in that criterion the "health" part and the "economic costs" in favor of the first part and the result will evidently change.

With the criterion W we set previously, we clearly see that for deterrence not to be overly costly (in the sense of this criterion), it will potentially be necessary for the public authority to cooperate using three tools: make the control test (moderately) sophisticated while increasing the fines, this increases the cost of circumvention paid by the firm while increasing its cost in case of identification, and thus the profit the public authority will make from the fraud. The third lever, which can also play in favor of deterrence at the perfect equilibrium, is setting the environmental regulation at a reasonable level. This sort of strategy reduces the cost of compliance, thus decreasing the temptation to commit fraud. Furthermore, the required level of sophistication of the public control test for fraud deterrence (logically) decreases in relation to the level of the environmental regulation: when the environmental requirement (authorized emissions threshold) decreases, the public authority test can be less sophisticated in deterring fraud, because the cost of conforming is more bearable and therefore an increased sophistication can be compatible with the objective to minimize criterion *W*.

By taking this observation into account, the expression of the firm's total expected profit and the difference is Δ; we can then derive a summary of factors that favor fraud deterrence and its emergence as a solution for perfect equilibrium:

F1 – *Competition in the sector is relatively weak* (concentrated sector). When competition is relatively weak in the sector, the firm can obtain a comfortable profit and the temptation to take a risk and commit fraud decreases.

F2 – *The public authority can deter fraud at a cost that is acceptable for the community*. Such a scenario is possible either because of the technological capacity to access sophisticated tests at a low cost or the inability for the firm to find or acquire a circumvention process at a low cost. The idea is that in the end, the "competition" that the public authority could engage in with the firm (control test/circumvention process) turns in the public authority's favor: The latter can easily and cheaply up the ante.

F3 – *Public authority regulations* $\bar{q}$ *are not too restrictive.*

F4 – *Fines and compensation in the event the fraud is identified as relatively high*.

F5 – *The NGOs are powerful and particularly vigilant.* Deterrence then comes from the probability of being identified increasing and makes paying fines and other compensation relatively probable.

4.5.2. *Perfect equilibrium with the firm committing fraud*

In this case, the public authority gives up on deterring fraud in the name of collective interest (sanitary cost and sophistication cost for the control test).

These are the opposites of the propositions mentioned previously (factors F1–F5), which this time favor achieving a perfect equilibrium that includes fraud. We will not revisit these factors but rather discuss here the added complexity to the analysis from the variety of possible equilibriums we can achieve with fraud. We can indeed obtain different types of perfect equilibriums differentiated by the intensity of the fraud (level of breach of the regulatory standard and number of vehicles involved).

When the public authority does not find it advantageous to implement measures to avoid fraud, it can nonetheless control its intensity by enticing the firm to commit fraud on only a small number of vehicles and/or the level of breach of the maximum authorized emissions.

4.5.2.1. *Strategic arbitration for the firm*

In the process that leads a firm to choose a given couple (n,q), rather than another in response to a triplet $(\bar{q}, \theta, R)$ decided by the public authority, there are strategic arbitrations that the firm faces. Let us begin by discussing these arbitrations.

The choice of the scale of the fraud (number of non-regulatory vehicles) and its intensity (emissions above the standard) depend on the effects of this combination on the total expected profit of the firm:

$$\pi(\theta, \bar{q}, n, q, \gamma) = \bar{\pi}\,(N-n, \bar{q}) + \tilde{\pi}_2(\theta, \bar{q}, n, q, \gamma)$$
$$-\phi(q, n, v)C(q, n, R)$$

The part $\bar{\pi}\,(N-n, \bar{q}) + \tilde{\pi}_2(\theta, \bar{q}, n, q, \gamma)$ increases with the number n of non-compliant cars and the emissions q because more than one vehicle are equipped with fraudulent motors, moving further and further away from the authorized threshold, the more companies save money and increase competitiveness. But this benefit is countered by the behavior of the second probabilistic part of this benefit $\phi(q,n,v)C(q,n,R)$. This part of the profit also increases with n and q *via* the probability $\phi(q,n,v)$ of being caught. The whole problem is to know whether n or q increases that probability fastest.

When the firm must arbitrate between a high number of low-polluting vehicles (scenario S1) or a low number of high-polluting vehicles (scenario S2), it must indirectly respond to the following question: Does S1 or S2 raise more suspicion from the NGOs? The answer to this question will determine the tendency that will predominate in the firm's decision between one or the other scenarios.

Formally, the question is to study the mathematical variation of the function $\phi(q,n,v)$ in relation to n and q (partial, second and cross derivatives). Many behavior scenarios of this function can be considered, each corresponding to a reality of the methods and activities of the present NGOs. This function could, for example, reflect the idea that as the number of vehicles involved in the fraud increases, the emission levels (differential from the standard) associated with these vehicles, even the low-polluting ones, risk raising suspicion and launching an alert. In other words, when q is low, the probability of an investigation could increase further when the number of vehicles involved increases. This level of variance could also be higher when the level of emissions is stronger than it is weak. Symmetrically, a similar behavior of the function $\phi(q,n,v)$, when it is the rate q that varies and n is given, is also plausible and can complement the previous scenario.

We have not discussed this idea further. The idea is simply to signal this stage of the strategic consideration, which makes it necessary to assess this function $\phi(q,n,v)$ and to collect the most information possible on the operation of NGOs to get an idea of their behavior.

To conclude, note that the probability $\phi(q,n,v)$ increases with v (increased vigilance of NGOs), which means that as NGOs become more vigilant, and the fraud alert will be given for lower scales and intensities than before. Since the Dieselgate scandal, there have been debates on how to increase control levels (post-control tests) and deter fraud. These debates, certain actions and advances at European level (Box 4.5) in this direction can all be interpreted, in the context of our strategic representation of this case, as actions tending to reinforce the probability $\phi(q,n,v)$, by increasing of value of parameter v (or the efficiency of the control test).

> "The European representatives have taken a step towards a more efficient control system for Diesel engines, voting by a large majority on Tuesday April 4, for the recommendations of the investigation committee on measuring emissions in the automotive industry. But parliamentarians did take this logic as far as the committee – nicknamed 'Dieselgate' – would have liked, as it was hoping to see the implementation of a European watchdog agency. The investigators considered that this would have reinforced the cohesion and efficiency of controls by transcending the national scale. 'Parliament missed the opportunity to grant the European Union with a European watchdog that would have made cheating impossible', considers Karima Delli, the vice president (groupe des Verts-Alliance libre européenne) of the EMIS commission. This opinion is shared by the Socialist group at the European Parliament and by the NGOs Réseau Action Climat (RAC), France Nature Environment and by the consumer association UFC-Que Choisir which, in a joint statement on Tuesday, denounced a '*lack of ambition*'. According to them this European agency was '*the only thing able to guarantee a harmonized approach in regards tests and surveillance on the market*'".
>
> Source: http://www.lemonde.fr/planete/article/2017/04/05/les-timides-avancees-europeennes-pour-eviter-un-nouveau-dieselgate_5106040_3244.html.

Box 4.5. *Propositions for making control tests more efficient: acting on θ*

Similarly the part $\phi(q,n,v)C(q,n,R)$ of the profit increases with R *via* the cost $C(q,n,R)$. The public authority therefore has the possibility to incite the firm into moderating the scale and intensity of the fraud on one condition: the fine R not be pre-determined but rather indexed on the intensity q and the scale n of the fraud. If the fine is pre-determined, it is the amount of compensation that depends on the extent of harm, which will play this role.

Concrete solutions resulting from the Dieselgate case were issued in order to reduce the occurrence of fraud in this field. A large number of these actions refer to the parameters of intervention levers presented in this chapter (v, R, θ). The same article in Le Monde, presented in Box 4.5, accounts for these possibilities (Box 4.6).

> "… In the face of this scandal, the representatives are asking the Commission and the Public authority to *'clean up their practices'*. They are proposing a series of non-mandatory recommendations such as the implementation of trial conditions of vehicles that would *'unpredictably vary the normal conditions in order to detect potential illegal invalidation devices'*. In the absence of the establishment of an agency, a 'forum' involving third party observers – such as NGOs – could be created to improve control tests. Consumers impacted by the scandal should also receive financial compensation from the car manufacturers involved. An injustice fixed by the Socialist Eurodeputies, who denounced the fact that *'In the US, Volkswagen reached a 10 billion dollar settlement* [9.4 billion euro] *with its American clients, while here they are refusing to pay for the damage suffered'*. Similarly to the vote on the recommendations by the EMIS commission, the parliament adopted, by a large majority, the European Commission's proposal to review the rules surrounding vehicular controls. It aims to improve audits performed by testing centers and by governing bodies. *'Each year, the member States of the European Union should control at least 20 % of vehicle models reaching the market within their country the previous year'*, states the text, and the manufacturers that falsify results could be made to pay up to 30 000 euro in fines per vehicle."
>
> Source: http://www.lemonde.fr/planete/article/2017/04/05/les-timides-avancees-europeennes-pour-eviter-un-nouveau-dieselgate_5106040_3244.html#L7RmZuw69KdeHTAS.99

Box 4.6. *Propositions for deterring fraud: acting on θ, v and R*

4.5.2.2. *Strategic arbitrations for the public authority*

What are the strategic arbitrations that can explain the public authority's choice to orient the firm toward an equilibrium where fraud will prevail?

If such an equilibrium is observed, it means that from the point of view of collective interest (criterion W), it is preferable that fraud takes place (eventually moderated on n and q) rather than not take place.

We can understand, as highlighted earlier, that the public authority does not wish to deter fraud by the relatively high economic cost $H(\theta)$ linked to the development of tests that are hard to circumvent for the firm.

With deterrence being too costly, let us now discuss the typology of the fraud (scale, intensity) that the authorities can choose to incite through their choice at the first stage of the game. Let us consider the particular following scenarios:

S1 – Play a triplet of actions $(\theta_0, \bar{q}_0, R_0)$ at the first stage, to incite the firm into choosing a relatively low number of vehicles $n_0(\theta_0, \bar{q}_0, R_0)$ and a relatively high level of pollution $q_0(\theta_0, \bar{q}_0, R_0)$ (and therefore a high breach level of the regulatory threshold).

S2 – Play a triplet of actions $(\theta_1, \bar{q}_1, R_1)$ at the first stage, to incite the firm into choosing a relatively high number of vehicles $n_1(\theta_1, \bar{q}_1, R_1)$ and a relatively low level of pollution $q_1(\theta_1, \bar{q}_1, R_1)$.

We assume that scenarios S1 and S2 can be perfect equilibriums of the game, meaning:

$$\left|\begin{array}{l}[n_0(\theta_0, \bar{q}_0, R_0), q_0(\theta_0, \bar{q}_0, R_0), \gamma(\theta_0)] = MR_E(\theta_0, \bar{q}_0, R_0) \\ \\ [n_1(\theta_1, \bar{q}_1, R_1), q_1(\theta_1, \bar{q}_1, R_1), \gamma(\theta_1)] = MR_E(\theta_1, \bar{q}_1, R_1)\end{array}\right.$$

with:

$$\left[\begin{array}{l}n_0(\theta_0, \bar{q}_0, R_0) < n_1(\theta_1, \bar{q}_1, R_1) \\ q_0(\theta_0, \bar{q}_0, R_0) > q_1(\theta_1, \bar{q}_1, R_1)\end{array}\right.$$

We chose these particular scenarios for the interesting dilemma they implicate for the state's decision.

The public authority's choice between the two scenarios S1 and S2 will depend on the answer to the following two questions:

Q1 – Between S1 and S2, which is the least detrimental for the health of consumers and the environment?

Q2 – Of these two scenarios, which is the most (financially) costly for society?

Questions Q1 and Q2 are a direct result of the decision criterion: $W(\bar{q}, \theta, R) = C_S[n(\theta, \bar{q}, R), q(\theta, \bar{q}, R), \bar{q}] + H(\theta)$.

Q1 is outside the domain of economics and management. The answer can only come from technical studies performed by experts in health-related fields (toxicology, epidemiology, etc.), or ecologists and so on. This does not remove from the fact that the government needs to answer this question to navigate rationally and with full knowledge between both scenarios.

The answer to Q2 is complex and depends, among other things, on the probability of an investigation depending on n and q. In order to accurately answer Q2, it is necessary to compare the two triplets $(\theta_0, \bar{q}_0, R_0)$ and $(\theta_1, \bar{q}_1, R_1)$ to distribute the effects on the different parts of W when we go from the first to the second triplet. We cannot have here a reasoned intuition on the comparison of levels of both triplets and their effects on W for one simple reason. Each of the parameters $(\theta, \bar{q}, R)$ has a direct effect on W, effects that are directly visible in the first expression W, (i.e. $W(n, q, \bar{q}, \theta) = C_S(n, q, \bar{q}) + H(\theta)$). But they also have indirect effects when considered in the context of strategic interactions between the firm and the state. For example, we know that θ acts upon H but it can have an indirect effect on the first part $C_S(n, q, \bar{q})$ of the expression of W: by generating an increase in n, the public authority forces the firm to use a more costly circumvention process, which thus has an incentive to compensate this additional cost by involving more cars in the fraud and/or increasing the level of emissions. Therefore, a variation of θ can have positive effects on all components of the criterion W. It is therefore difficult to derive intuitive results from an initial analysis of the variations in the levels of these two triplets.

We see that one or the other of these two scenarios S1 and S2 can be chosen by the public authority depending on the specifics of the functions $\bar{\pi}$, $\tilde{\pi}_2$ and ϕ, which determine the reaction of the firm to the public authority's strategy, and functions C_S and H, which constitute an indicator of the effect of this reaction on the collective well-being.

As it is not this chapter's aim to entirely solve the problem, but rather to highlight the elements for strategic consideration that will allow us to understand the implications and the fallout of Dieselgate, we will not discuss this question any further.

4.6. Conclusion

The recent revelations of emissions fraud have tarnished the reputations of many car manufacturers. What has commonly been dubbed as "Dieselgate" has raised numerous questions, one among which pertains to the difficulty for governing bodies to sustainably enforce environmental regulations onto certain operators. These operators may be involved in global competition where anything goes, even if it sometimes goes against legal regulations. The second question deals with the difficulty for companies to implement equivocal corporate social responsibility (CSR), which they often commit to for following the guidelines.

Why do VW and other operators make the decision to go against the law and take that risk, which involves paying a high price for now at the time of writing, both in compensation and other fines but also in the damage to their image? This chapter attempted to answer this question: are there conditions that will create an incentive for such behavior? We performed the analysis by assuming that companies are driven by strict economic rationality, beyond ethical considerations. In this sort of frame of analysis, fraud is an endogenous decision, resulting from strategic interactions between businesses and the government.

What determines the decision to defraud firms is the result of arbitration. It is a comparison between what firms can gain from fraud and what to anticipate as loss. "Illegal" profit (based on the number of fraudulent vehicles) is detected as long as the firm is not identified. "Being unidentified" is uncertain. Whether it is achieved, or the probability of this achievement, depends on the decisions made by the firm. To increase this probability of being undetected, involves reducing the temptation to defraud mechanically. Increasing fines is therefore not sufficient. The likelihood of detecting fraud should be addressed and this may involve modifying control typologies and their reliability. If fraud is not entirely discouraged by highly efficient controls, then demanding the implementation of environmental standards can reassure the consumer and the everyday citizen. Nevertheless, they are not the most effective means for protecting the consumer and the environment.

This chapter has shown how, with regards to the environment and consumer health, it might be more effective to lower the required standards in order to minimize the intensity and level of fraud. If society accepts a certain amount of fraud, less demanding regulations (neither highly flexible nor ambitious), because they constrain companies' market performance, then this will lead to less scope for fraud to take place.

The analysis shows how far we can take this logic when using simple tools of game theory and how we can then obtain subtle results that supplement strategic analysis.

However, the Dieselgate case is but an example of a typology of phenomena that can be observed in other sectors. The agri-food industry has given us some of the most striking examples, due, in most cases, to their consequences on consumer health (mad-cow disease, dioxin chicken meat, Chinese contaminated milk, the horse-meat scandal, etc.). All of these examples have one thing in common. First, they harken for market regulations to protect consumers and/or the environment when the market alone is not able to spontaneously offer the guarantee of protection. Furthermore, they highlight the flaws of these regulations in the face of strategic incentives of certain operators, which sometimes lead to the use of sophisticated expertise.

The methodology used in this chapter consisted of a presentation of textbook cases, by using a typology of games (sequential games), which demonstrated its usefulness for identifying dynamics in interactions and behavior, which intuition alone may not have revealed. The underlying strategic considerations of this case, which are, ironically, not often highlighted in current debates, can therefore be essential to understanding the interactions between public authorities and private operators. In certain cases, they can explain the success or failure of implemented regulations.

5

Application 2: Emergence of Food Safety Standards

5.1. Introduction

One of the major issues in the agri-food industry concerns the measures that need to be deployed in order to ensure food safety for consumers. After the health crises that took place in the 1990s, particularly at the European scale, more and more severe public regulations were issued with the aim of disciplining the players in the sector and protecting the health of consumers. A set of standards was drawn up, some of which were essentially public (references laid down by public authorities or the European Commission, Box 5.1), and others were of a private nature (some of them designed by the actors themselves), in order to serve as guidelines for production, processing and marketing practices.

Private standards represent an important part of the initiatives undertaken by the private actors at the moment of improving the safety of the products they deliver to consumers. These standards aim to simplify a series of specifications imposed by European retailers and by the food industry on their suppliers (and in some cases, on the industry itself).

Game Theory Approach to Managerial Strategies and Value Creation,
First Edition. Abdelhakim Hammoudi and Nabyla Daidj.

There are two main standardization organizations active in the international sphere: (1) the International Organization for Standardization (ISO), which develops standards in different fields and sectors, extending to a wide range of products, services and management systems; and (2) the Codex Alimentarius Commission (CAC), which establishes regulations on quality and food safety (including hygiene or technology codes of practice). This organization is in charge of establishing limits for pesticide residues and contaminants, as well as of offering recommendations on rules for the development of national regulations in the field of food safety. European food safety legislation is based upon a number of regulatory instruments that define the maximum permitted threshold for contaminants (aflatoxins, dioxins, heavy metals; Reg. 1881/2006) or pesticide residues (Reg. 396/2005) in foodstuffs as well as "hygiene packages" (Reg. 852/2004 and Reg. 853/2004 on foodstuffs hygiene). Apart from issuing legislation, official control systems are designed to verify compliance with feed and food laws.

Box 5.1. *Public approaches to food safety. International and regional approaches to food safety regulation*

There are individual standards designed by the firms for themselves and there are other standards – known as collective standards – which are designed in a concerted manner by business coalitions. In other words, one of the aims of these collective standards is to harmonize the different specifications that retailers (that is to say, the most active players in the field) impose on their suppliers. Some of these standards, individual or collective, have the common characteristic of emerging as a result after internal B2B-type processes take place in the sector. In other words, as far as collective standards are concerned, the idea is to define a common standard that can account both for firm agreements and for individual standards, through the implementation of a unique standard that every firm simultaneously imposes on itself as well as on its suppliers. Many of these standards are of the B2B type and are not communicated to consumers. For example, a retailer or an agri-food company creates a standard or a specification that he imposes on any supplier who wishes to go through his marketing circuit or to benefit from a supply contract. Unlike B2C standards, products subject to B2B standards and sold on the final market do not carry a stamp or a label that distinguishes them from other "generic" products that have not received this specification. As a consequence, specifications such as B2B do not constitute an element of differentiation from competitors. In principle, neither the firm nor its suppliers can expect a reward (or a premium price) from the consumer for the efforts provided (see examples of private standards in Figure 5.1). So the question is: what is it that motivates these firms, if, *a priori*, their efforts are not remunerated by consumers?

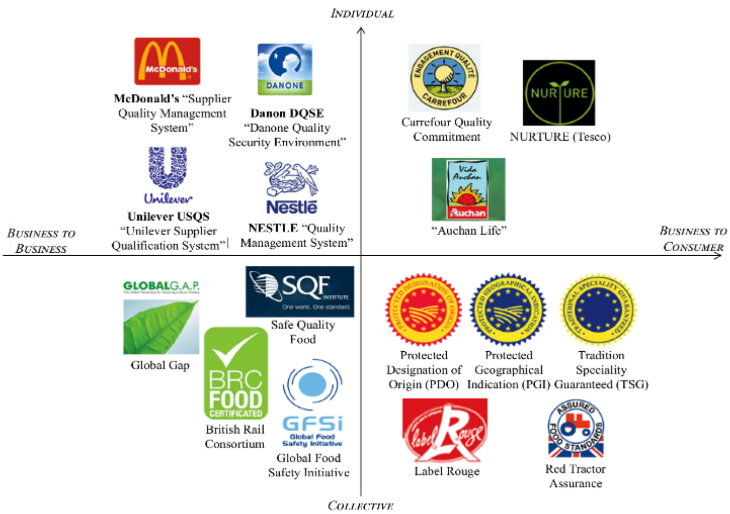


Figure 5.1. *Examples of individual private, collective, B2B and B2C standards [GIR 13]*

The strategic motivations of firms to engage in this type of approach have been the subject of ample debate in the literature of agricultural economics. One of the most frequently quoted explanations is that retailers, who acquired relevant experience through the lessons learned from the crises and the repeated health incidents that took place in the 1990s, clearly understood that crises are harmful to their business, and even more so for the operator who is directly responsible for it. A crisis may also affect the sector as a whole, which could account for the coordination initiatives taken so as to create a collective standard. Food security is a “good” in which all actors should invest, because in the event of a crisis, firms could see their income collapse due to a partial or a total boycott from the part of the consumer. Therefore, the motivation of firms should not be to obtain a reward from the consumer, but to take anticipatory measures in order to prevent a potential boycott.

This fear of being sanctioned by the market can be one of the possible explanations for the emergence of private standards [HAM 09]. A second explanation is the fear, in case of an incident or a sanitary crisis, of having to pay large fines to the government or, moreover, if the incident seriously affects the health of consumers, of having to pay compensation to the victims, according to the legislation in force.

From this factual inventory, we now try to build up a game that reveals the strategic compromises that firms have to face when deciding whether to develop an individual standard or, on the contrary, to satisfy only the public regulations that represent the minimum threshold that must be respected in order to carry out their activities. To simplify the argument, we restrict our analysis to two firms and evaluate under what conditions an economy of private standards can emerge.

5.2. The game

The set of players is restricted to two firms, 1 and 2. The firms must decide whether they are willing to adopt a B2B-specific standard. If they decide not to adopt the standard, as pointed out earlier, this means that the firm will engage itself to comply with regulations in force at the same time that it will refrain from going a step beyond, by creating its own standard.

The strategy for each player i, i = 1, 2 is $x_i \in \{Yes, No\}$. We basically assume that the adoption of a standard reduces global food risk, but that this risk may even become lower when the two firms engage in such an approach. In other words, the more precautions are taken, *via* the generalization of standards, the greater the security.

The r risk that a crisis could eventually occur depends on the decision of 1 and 2 with regard to the creation of a collective private standard, which we assume is B2B. Parameter r represents the probability of a crisis taking place and is therefore a function of the decisions of the firms:

$$r \equiv r(x_1, x_2), \text{ where } r\,(yes, yes) < r\,(no, yes) = r\,(yes, no) < r\,(no, no)$$

We suppose that the adoption of a standard by firm i, ($i \in \{1, 2\}$) induces an F_i cost, which is assumed by fixed simplicity. The costs of establishing regulations or adequate production practices may be of different kinds, according to a wide range of expenditure categories (Box 5.2).

The costs of implementing best practices (or practices in compliance with standards and regulations in force) may refer to the application of good hygiene and manufacturing principles, as well as the setting up of on-spot controls and/or the application of the HACCP (Hazard Analysis Critical Control Point) method. Depending on the case, some flexibility may be left to actors to choose from the existing Good Practice Guides panel (advocated by organizations such as the EU (European Union) or the Codex Alimentarius). The costs incurred largely depend on individual choices and are consequently very heterogeneous, depending on the modules that the operator chooses (or is imposed under private standards). The implementation of these practices, however, involves a number of expenses, which contributes to increasing the initial investment: there is an initial fixed cost for setting up a quality system, and then there is the cost of improving infrastructure, staff training, audits and certifications (compensation of experts, issuing the certificate of conformity, etc.). On the other hand, certificates with a limited validity period are likely to generate a periodic expenditure flow. Another category of costs is associated with controls. This includes research costs and those associated with imput substitution, a cost that arises from the need to search for substitutes for a large number of products traditionally used in pest control, all of this, in line with the development of a European regulatory system that rules pesticide registration and tolerance thresholds of Maximum Residue Levels (MRLs). Compliance costs may also be recurring (maintenance costs and regular monitoring of laboratory testing programs as well as additional production costs related to enhanced food safety checks) or non-recurring (improvement of infrastructure, laboratories and processing facilities, implementation of new procedures and staff training, design of new management systems).

Box 5.2. *The costs of implementing best practices in compliance with regulations in force*

The turnover of each firm is noted as CA. Whatever the standardization decision taken, both firms are expected to obtain the same turnover (CA). In other words, we are confronting the specific case in which standardization neither improves nor reduces demand and selling price, because in a B2B standardization framework, the consumer cannot differentiate the standardized product from one that is not.

In this case, how could a health crisis affect the income of firms? We assume there are of two types of consequences:

– A penal sanction (penalty sanction) that we note as $\Gamma_p(x_i)$, which is paid by Pi when it played x_i . This penalty may result, for example, in fixed fines established by the government and/or compensation for the victims of the crisis. This function is more or less important depending on whether the firm has followed a regulation, that is to say, there is proof that the firm has done everything possible to avoid the advent of a health incident. A proof of such a nature may eliminate the penalty ($\Gamma_p(x_i)$).

– A market sanction that we note as Γ_m, which represents the shortfall due to consumer boycott as well as the fall in the demand.

The earnings Π_1, Π_2 expected by producers $\mathit{\Pi}1$, $\mathit{\Pi}2$ who have simultaneously chosen strategies $(x_1, x_2) \in \{yes, no\} \times \{yes, no\}$ are formally written as:

$$\Pi_1(x_1, x_2) = CA - F_1(x_1) - r(x_1, x_2)\Gamma_p(x_1) - r(x_1, x_2)\Gamma_m$$

$$\Pi_2(x_1, x_2) = CA - F_2(x_2) - r(x_1, x_2)\Gamma_p(x_2) - r(x_1, x_2)\Gamma_m$$

In general terms, the payoff matrix is written as:

$$\begin{array}{ccc} & & J2 \\ & & \text{Yes} \qquad\qquad\qquad \text{No} \\ J1 & \begin{array}{c}\text{Yes}\\ \text{No}\end{array} & \begin{pmatrix} \Pi_1(yes, yes) & \Pi_1(yes, no) \\ \Pi_1(no, yes) & \Pi_1(no, no) \end{pmatrix} \end{array}$$

Let us take the question one step further. Among the variables that influence the decision of the firms in this game matrix, we have a Γ_m and Γ_p. The value of Γ_m depends on the market's response to the crisis, that is to say, first, the behavior of consumers after the health incident. In the event of a crisis, we suppose that this is a situation that we may encounter in real life (Box 5.3), but which is not exclusive.

The crisis of "enterohemorrhagic *Escherichia coli*" (noted *E. coli*) in 2011 provides the typical example of widespread consumer boycott. The *E. coli* crisis, caused by sprouting seeds from Egypt, caused approximately 4,000 pathologies in Germany, 130 cases in 12 European Union countries, a dozen cases in Canada and the United States. In the period of 3 months, from May 2011 to July 2011, it caused 76 deaths in Europe. The prudential behavior of consumers after the outbreak of the crisis affected not only the Spanish producers (wrongly) designated as responsible for the crisis (as it would become known later), but also the incomes of sectors such as tomatoes, lettuce, etc. Consumers not only responded during the crisis but even after the warning on cucumber was lifted, they boycotted more or less every kind of raw vegetable. Although Belgium decided to ban the imports of Spanish cucumbers, Russia banned every vegetable import from Spain and Germany. For further information, see the report: http://documents.irevues.inist.fr/bitstream/handle/2042/48818/AVF_2012_4_347.pdf? Sequence = 1.

Box 5.3. *An undifferentiated market sanction. The example of the E. coli crisis in 2011*

Γ_p largely depends on legislation and, in a certain way, on the decision of public authorities. Therefore, it would be useful to involve the government in the game. This may be done, for example, by having the government participate in the first stage of a sequential game through the determination of fines (and other compensation-related rules) linked to a health incident, which corresponds to a level of Γ_p. In the second step of such a game, Γ_p, being fixed and observed by the firms, these can play the game represented by the preceding matrix. In other words, the game is the following:

– First stage: The government sets the Γ_p level of penalties in case of crisis.

– Second stage: Firms observe Γ_p, and simultaneously choose their decision *Yes* or *No* by anticipating Γ_m.

We assume that the game handles complete and perfect information. The government is supposed to anticipate the outcome that prevails during the second stage of the game. The resolution of the game is done by *backward induction*. We start our analysis at the second step of the game. We determine the outcome of the game matrix, which is a function of Γ_p, and then, from this information, we imagine ourselves in the role of the government to determine the value(s) of Γ_p, which yield(s) the best level of "gain" for the government, a payoff that still remains to be specified. To simplify the argument, we assume that the government's payoff is the one that safeguards the health of consumers. By the way in which it was built, our model assumes that health risks are reduced when both firms choose to create a private standard. Then, we consider that the government will tend to influence, through Γ_p choice, the outcome of the second stage of the game, as a means of promoting the advent of the option (*Yes*, *Yes*).

5.3. Nash equilibrium

In order to keep the reasoning simple, we reason following a numerical example:

$$CA = 100$$
$$F_i(yes) = 5,\ i \in \{1,2\}$$
$$r(yes, yes) = 1/5$$
$$r(yes, no) = r(no, yes) = 1/3$$

We consider the risk associated with the absence of private standards as a variable parameter in order to study the influence of this parameter on the strategic decisions of firms. We then set $r(no, no) = r, 0 \leq r \leq 1$. We equally set $\Gamma_P(Yes) = 0,\quad \Gamma_P(No) = \Gamma_P$, which means that the firm has done everything to avoid a health incident and will not have to pay for a fine in the event of a crisis, whereas the firm that does not have any kind of evidence will have to pay for it. Of course, we assume that the health crisis is diffuse in the sense that we cannot identify with certainty who was at its origin, but the evidence provided by the firms in charge of security beyond compulsory public procedures suffices to reduce the fine incurred. We also assume that the market sanction in the event of a crisis will affect both firms in the same way and that the consumer will not make a difference between the firm that adopted a standard and the one that did not adopt it.

The payoff matrix is then the following:

$$\begin{array}{cc} & J2 \\ & \begin{array}{cc} \qquad\qquad Yes \qquad\qquad & \qquad\qquad No \qquad\qquad \end{array} \\ J1\ \begin{array}{c} Yes \\ No \end{array} & \begin{pmatrix} \left(95 - \frac{1}{5}\Gamma_m, 95 - \frac{1}{5}\Gamma_m\right) & \left(95 - \frac{1}{3}\Gamma_m, 100 - \frac{1}{3}\left(\Gamma_p + \Gamma_m\right)\right) \\ \left(100 - \frac{1}{3}\left(\Gamma_p + \Gamma_m\right), 95 - \frac{1}{3}\Gamma_m\right) & \left(100 - r\left(\Gamma_p + \Gamma_m\right), 100 - r\left(\Gamma_p + \Gamma_m\right)\right) \end{pmatrix} \end{array}$$

Having established the payoff matrix, we can now investigate different concepts of game solutions and compare the results obtained as well as their impact on the strategic and economic plan. We limit ourselves to finding Nash equilibria – if such equilibria exist – and solutions composed of prudent strategies.

To determine the Nash equilibrium of the game, it is necessary to calculate every possible strategy for each player and, for each of these, the best possible answer from the other player. The outcome for which the strategy associated with each player is the best answer represents the game balance. For the moment, let us concentrate on two outcomes that are of particular interest given their extreme (positive or negative) effects on consumer health: outcomes (*Yes*, *Yes*) and (*No*, *No*).

By applying this rule to determine equilibrium, which simply corresponds to the definition of a Nash equilibrium, we can easily verify that (*Yes*, *Yes*) constitutes a Nash equilibrium if and only if $\Gamma_P > 30 - \frac{2}{5}\Gamma_m$ (relation 1) and (*No*, *No*) is a Nash equilibrium if $\Gamma_P < \frac{10}{r} - \frac{1-3r}{3r}\Gamma_m$ (relation 2).

The other interesting question that can be added to the analysis is when, apart from the conditions for equilibrium, the situation in which the two players create a private standard is better than the one in which they decide not to create such a standard. In other words, under what conditions does the Pareto (*Yes*, *Yes*) outcome dominate the (*No*, *No*) outcome?

The answer to this question depends on the simultaneous comparison of the differences between $\Pi_1(Yes, Yes)$-$\Pi_1(No, No)$ and $\Pi_2(Yes, Yes)$-$\Pi_2(No, No)$. If these two differences are strictly positive, then we can conclude that the Pareto outcome (*Yes*, *Yes*) strictly dominates the (*No*, *No*) outcome. It is easy to verify that the condition for the Pareto (*Yes*, *Yes*) strategy to dominate (*No*, *No*) is $\Gamma_P > \frac{10}{r} - \frac{1-5r}{5r}\Gamma_m$ (relation 3).

To illustrate these results, we outline relations R1, R2 and R3 on the same abscissa axis $\Gamma_m$and ordinate axis Γ_P . In this way, we can visualize the areas formed by pairs (Γ_P, Γ_m) for which the (*Yes*, *Yes*) and (*No*, *No*) outcomes are Nash equilibria of the game and the areas where one of the two Pareto outcomes dominates the other.

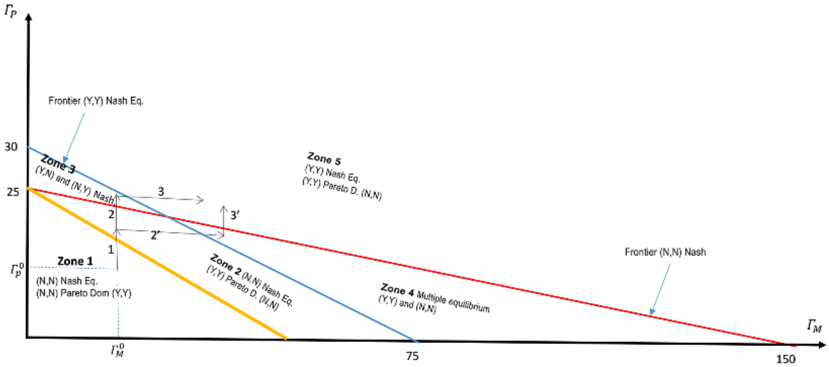


Figure 5.2. *Equilibrium outcomes*

A certain number of lessons can be drawn from the analysis of the different zones highlighted in Figure 5.2. First, this analysis enables us to identify the strategic incentives of firms depending on the level of penal and market sanctions. It also helps us determine the adjustments to be made by the public authorities in terms of fines, so as to eventually compensate for a penalty insufficiency imposed by the market in the event of a health incident. In other words, the penal sanction set by the government during the first stage of the game must be strategic in the sense that it must be chosen in such a way as to orient the balance of the second stage of the game in a direction that, from the perspective of this authority, is the best for public interest.

We may summarize the analysis by listing its four main teachings:

– First teaching: *at the Nash equilibrium, both firms may choose not to create a standard and this situation may be collectively satisfactory for the firms compared to the situation when they create their standards*.

This case emerges when the two sanctions, penal and market, are relatively feeble (e.g. equal to (Γ_M^0, Γ_P^0)). From the perspective of individual rationality as well as from collective rationality, it is not in the interest of the firms to create their own standards or, broadly speaking, to improve their production or processing practices. The weakness of the sanctions does not encourage the implementation of best practices: even if the risk of provoking a crisis is high, both operators choose to take this risk because the sanctions incurred have a low impact on the costs that the creation of a standard would generate. Here, we note that the solution would have been different if, in our hypotheses, we had admitted a differentiated sanction of consumers exclusively targeted toward the two operators who did not have a specific standard (B2C context in which the standard effectively constitutes a label communicated to the consumer). Nevertheless, we must bear in mind that this first teaching, corresponding to zone 1 in Figure 5.1, is the worst result that can be obtained from the point of view of public health (taking into account the correlation hypotheses between the implementation of regulations and the level of health risk). It is particularly in this type of situation that public intervention would be most desirable. A useful intervention tool would be to increase the value of the penalty (Γ_P fine) so as to take the outcome away from the equilibrium area of the game in zone 1. Another intervention, which happens to be frequently mentioned in the literature and is in fact considered as one of the possible explanations that account for the emergence of private standards is for the public authorities to threaten the operators with the creation of a regulation (or a public standard), of a binding nature, in case they decide not to take the initiative themselves (see Box 5.4).

A branch of the economic literature attributes the emergence of such private standards to the fact that firms fear, if they do not make enough efforts at their level, they may trigger the creation of public regulations that could be even more restrictive or at least badly adapted to the features of firms. In other words, public regulations may prove more costly than the standards firms could develop themselves, by adjusting them to their capabilities. If we refer to a game between the public authorities and the firm, this would correspond to a generic game as proposed in the literature [GRA 15] where, during the first stage of a sequential game, the firm must decide whether to establish a private regulation; and in the second stage, the public authorities may decide, in the light of what was decided during the first stage, to issue a relevant standard (or not), by imposing the authority of public regulation. It should be noted that, in broader terms, the game is representative of the interaction between the public authorities and an entire "industry", in this case, embodied by the leading firm. The fact that the public authorities become involved at the second stage of the game gives them the possibility of implicitly or explicitly brandishing a threat to the firm ("if you do not set your own standard, I will issue a public regulation").The whole problem is of course whether such a threat is credible [SEL 65]. The regulation threat that the public authority can address to the firm if the latter decides not to set up a private standard must be sufficiently binding if it wants to have a chance of bearing fruit. However, such a condition is not enough for dissuading the firm from circumventing the introduction of a standard. The threat must be credible. In other words, it is in the interest of the government to undoubtedly carry out the threat when the firm does not commit itself to the desired strategy, that is to say, the implementation of a standard. Is the execution of the threat the best reaction to the absence of a private standard? The answer is not obvious, because apart from the health benefits that the implementation of the public regulation would generate, the government must assess the social costs that could result from the implementation of the aforementioned standard. In general, the public consideration also takes into account the firm's income (which is one of the indicators of economic activity) as well as the consumer's surplus. The introduction of a public standard could therefore engender excessive social costs in terms of health benefits, to the point that the public authority may refrain from implementing such a standard or an excessively demanding legislation.

Box 5.4. *Public regulation as a threat*

– Second teaching: *both firms can find it collectively more profitable to create their own standard each (rather than not creating one), without having this situation emerge at the equilibrium of the game.*

This situation, which emerges for the pairs sanctioned in zone 2, corresponds to the case where the (Y, Y) Pareto outcome dominates over the (*N*, *N*) outcome, whereas the latter is the one that emerges at the equilibrium of the game. In zone 2, there is a conflict between collective rationality (leading to the adoption of (*Y*, *Y*)) and individual rationality (conducive to (*N*, *N*)). This situation is typically representative of a *prisoner dilemma* scenario.

An increase in the level of one or the other of the two sanctions (or both at the same time), which favors the passage from zone 1 to zone 2, does not make it possible to change the equilibrium outcome, but barely the dominance relation between (*Y*, *Y*) and (*N*, *N*): the (*Y*, *Y*) outcome is collectively preferred to (*N*, *N*). How can this result be explained? Be it in zone 1 or 2, the probability of a crisis is reduced by the same level when opting for a standard rather than when opting for none. The only thing that changes is that it costs more for both operators, because these have to pay a higher aggregate penalty when the crisis occurs in zone 2 (at least one of the two penalties (Γ_P, Γ_m) has increased in relation to zone 1). In zone 2, not creating standards is more disciplining, be it in terms of the fine that has to be paid in the event of a crisis or in terms of market penalties, depending on the variation in sanctions (Γ_P, Γ_m) from zone 1 to zone 2. The savings that they can engender when gliding from zone 1 to zone 2 in the situation associated with the creation of standard acts as an explanatory factor for the Pareto-dominance relation obtained in this area. However, if one of the two operators knows that the other will adopt a standard, the first one will tend to take advantage of the positive effects of the competitor's initiative (this will produce an effect on risk) by deciding not to adopt a standard itself. Nonetheless, sanctions in this area will still not be enough so as to encourage the firm to bear the costs of implementing a standard. The free rider or illegal passenger behavior can be defined as the act of taking advantage of the competitor's effort to enforce a regulation and to unilaterally reduce food risk, without having to pay for the price (that is to say, the cost of setting its own standard). This phenomenon jeopardizes the emergence of the (Yes, Yes) outcome. Not only does it explain why the (Yes, Yes) outcome will not emerge, but also the fact that this result will not be observed at the equilibrium of the game, considering that the outcome is (N, N).

We confront the phenomenon of the free rider in the situation related to the third teaching in the following:

– Third teaching: *for certain levels of market penalties and penal sanctions, there are multiple equilibrium outcomes when only one of the two firms creates a standard*.

In zone 3, there are two possible (symmetric) equilibria, in such a way that while one firm creates a standard, the other, following a free rider behavior, profits from the reduction in food risk generated by the action of its rival.

In this area, the best reaction of a firm to the creation of a standard by its competitor is to renounce the creation of its own standard. In order to understand this type of behavior, we must go back to the assumptions of our model (undifferentiated consumer boycott) and consider the numerical values used for solving it. By means of unilateral action (creating a standard), the firm contributes *de facto* to diminishing the risks of a food crisis. The competitor systematically benefits from such a reduction. The latter's response (creating or not creating a standard) will depend on the following three factors:

– How much will the risk level diminish if the firm decides to create its own standard, in comparison with the situation where it leaves the opponent to unilaterally do it?

– In the event of a crisis, what level of penalty the firm will have to face, knowing that this is the only type of sanction that distinguishes between the firm that created a standard and the firm that did not create a standard?

– What is the expected level of market sanction in the event of a crisis (bearing in mind that this level does not vary in function of the number of established standards)?

In order to meet the competitor's *Y* strategy, the firm will naturally take into consideration the three elements mentioned previously. It is clear that if the market penalty is not too high, the level of security generated by passing from (*Y*, *Y*) to (*Y*, *N*) is not significantly large and the penal sanction is not too heavy, the competitor will probably tend not to create a standard if the other firm creates it. In fact, the competitor will benefit from the reduction of the health risk associated with the approach of its opponent without incurring the cost it would have to face if it were to create its own standard. Now, we can understand why when the given market sanction is Γ_M^0, placing ourselves in zone 3, it is useful to increase the penalty so as to elicit a *Yes* response to the competitor's *Yes* strategy, and in that way, make it possible for the (*Y*, *Y*) outcome to emerge in zone 5. In this case, increasing the penalty contributes to the avoidance of free-riding practices, as this behavior is denominated in the English-speaking literature. Let us remark that the given reasoning is also valid at Γ_p^0 fixed in zone 3: an increase in the market sanction *via* strong consumer reaction also helps to prevent free rider behavior at the equilibrium of the game.

Finally, we should reckon that the hypothesis of an undifferentiated consumer boycott plays a non-negligible role in the advent of such an outcome. If we nuance this hypothesis (see Box 5.5), and under certain conditions (penal and market sanctions), the free rider behavior as an equilibrium outcome could be avoided in the same area.

– Fourth teaching: *a non-cooperative game (each firm creating its own standard) can lead both firms to choosing an outcome that is simultaneously collectively satisfactory*.

In zone 5, where such a scenario arises, only relatively high market or penal sanctions may induce the two firms to create a standard, while making sure that such an outcome is both individually rational (in the sense of equilibrium) and collectively desirable for firms.

In the event of a crisis, and in certain contexts, the consumer may adopt a discerning behavior, that is to say, only boycotting the operator who was responsible for the crisis. Under this hypothesis (the hypothesis of an "enlightened" consumer boycott), the matrix corresponding to the previous game becomes:

$$\begin{array}{cc} & J2 \\ & \begin{array}{cc} Yes & No \end{array} \\ J1 \begin{array}{c} Yes \\ No \end{array} & \begin{pmatrix} \left(95, 95-\frac{1}{5}\Gamma_m\right) & \left(95, \quad 100-\frac{1}{3}(\Gamma_p+\Gamma_m)\right) \\ \left(100-\frac{1}{3}(\Gamma_p+\Gamma_m), 95\right) & \left(100-r(\Gamma_p+\Gamma_m), 100-r(\Gamma_p+\Gamma_m)\right) \end{pmatrix} \end{array}$$

This matrix is built using the following assumptions. The one who does not set a standard anticipates that he can trigger a crisis with (1/3) probability and that the crisis can, *de facto*, be attributed to him. Another interpretation is that (1/3) represents the probability that the crisis is directly attributed to him. The underlying assumption is that, in the event of a crisis, the responsible actor can be identified, and that when confronted with the two operators (players 1 and 2), there is a perfect correlation between the non-implementation of a standard and the responsibility for a crisis. As we have done in sections 5.4 and 5.5, we can then practice looking for different solutions to this game.

Box 5.5. *Matrix game under the hypothesis of consumer discernment*

Starting from the right of the abscissa axis, from the *boundary line* (*Y*, *Y*) until the *boundary line* (*N*, *N*), we can observe that when the market penalty decreases, the government must compensate for such a diminution in the penal sanction if it wants to bring about equilibrium (*Y*, *Y*). We can clearly appreciate how consumer behavior in the face of a crisis can reduce the fine needed to orient the game's balance toward the (*Y*, *Y*) outcome. If the market penalty is high enough (right of the abscissa axis), that is to say, if we are dealing with consumers who react vigorously to a health incident, then the government does not need to set high fines in order to guide firms toward the desired outcome.

We note that the specificity of an outcome in zone 5 is such that it includes individual and collective rationality. This situation particularly leads to a concerted decision in the industry, which will agree on creating a regulation that reflects so-called private collective standards (see section 5.1 and Box 5.1). Cooperation in zone 5 for creating a coordinated standard will be robust against any unilateral deviation or denunciation of the agreement by any of the two parties.

5.4. Conclusion

The chapter addressed an issue for which the stakes are currently high and which falls within the more general framework of what is known as corporate social responsibility (CSR), with regard to the environment, the working conditions, consumer health, etc. It is a question of understanding the way in which the standards set up by the private actors for securing their marketed products emerge in the context of a B2B (inter-firm coordination) logic. The approach focuses, on the one hand, on a simple representation of the reality of the interactions among firms and, on the other hand, on the relation between the public authorities and the firms. The intention is to identify a certain number of mechanisms that explain the emergence of these standards. We have put into perspective the economic interest of firms in implementing best practices beyond purely ethical considerations. When economic considerations are consistent with or compatible with ethical principles, the criteria associated with CSR are obviously more practicable. In case of appearance of incompatibilities between these two criteria, it is public regulation that must predominate and permeate the actions of firms, by directing or constraining them. As such, the standard does not completely abolish the strategic freedom of firms, but only restricts their strategic space. Sometimes a reduction in the spaces of strategies through the enforcement of regulation is not necessarily contrary to the interest of some firms: by having an impact on the strategic space of all the firms, the standard may have a more negative effect on the response capacities of some specific firms (with less financial assets, less know-how and skilled labor, etc.). Thus, standards may change the industrial structure of the economy. Furthermore, regulating and implementing standards can be a way for public authorities to select and to orient competition toward situations that may be both desirable for business as well as for the community. In fact, we have seen how firms could orient themselves toward a (competitive) outcome different from the one they would collectively have wished for, without a specific public intervention (by means of fines or *via* threats). In this sense, regulation can play the role that a third party would play by orienting the trajectory of a non-cooperative game toward a collectively desirable outcome. Regulation can certainly do this by blocking deviant behavior (such as *free riding*, for example, on the case we studied). As we have observed, these deviant behaviors threaten the advent of a collectively desirable solution.

Although remaining an important initiative under the frame of CSR, private standards may spontaneously emerge as an optimizing strategic calculation tool, which is nonetheless opportunistic on the part of firms. We have seen how market sanctions as well as fines could encourage firms to adopt these standards in the event of a health incident. We also addressed the role that regulatory threats issued by public authorities could play in relation to firms that do not endorse this type of preventive approach. The regulatory environment must of course be well known to firms so that they are able to define their strategies in the "adequate" space, that is to say, the restricted area imposed by regulation. In addition, it is useful for defining what type of game or representation of reality is the most appropriate to stimulate its strategic thinking.

The lessons of this chapter, which may possess a value of generality, have been derived from the presentation of a deliberately simplified example. The method and hypothesis that structure the game come from a simple transcription, based on the matrix or extensive representation of a game as well as a number of industrial economics works often based on complex models themselves. From this point of view, the application we suggest reveals that, when a targeted transfer work takes place, it is possible to take advantage of research advances (here in the field of Agri-food Economics) so as to draw an important number of lessons in terms of strategic management.

6

Application 3: Petrol Stations

6.1. Introduction: price structure of a multi-store firm and fragilization of isolated competitors

When a firm has a large number of stores or points of sale, does this provide it with an extra advantage in terms of pricing policy over competitors who have a smaller number of stores? And more specifically, is it possible for such a firm (which we will call "multi-store"), in possession of a chain of stores geographically distributed over a certain territory, to coordinate prices on all of its points of sale in order to weaken its mono-product competitors in certain territories where the firm has a strong presence? In order to address this question, we take a particular case from the fuel sector as a reference point. We will deal with a real case of the merger that took place between TotalFina and Elf in 1999.

6.2. The facts

In July 1999, TotalFina launched a takeover bid over Elf Aquitaine. At the time when the offer was launched, two types of actors were active on the French market. The first type of actor involved firms in possession of a dense network of retail stations along the French road system (TotalFina, Elf, Shell, Esso and BP/Mobil), all of which owned more than 80% of petrol stations. TotalFina, with almost 40% of the market share, was the leader in the market. Elf, Shell, Esso and BP/Mobil held market shares that

Game Theory Approach to Managerial Strategies and Value Creation,
First Edition. Abdelhakim Hammoudi and Nabyla Daidj.

oscillated between 10% and 20%. The second type of players included firms with few or very few petrol stations along the motorways (Agiphad: 7 stations, Avia: 8 stations, Dyneff: 2 stations and Leclercwas, the last firm to enter the market). Taken together, these firms owned less than 2% of the total number of stations.

Due to the fact that the consumer is relatively captive on a motorway, the European Commission considers that the petrol station motorway market is a very specific type of market (a relevant one), which makes it typically different from off-highway fuel distribution points. Assuming that most operators of motorway petrol stations are vertically integrated refining tankers, these actors have an absolute and centralized control over the commercial policy of their motorway stations. There is a high price transparency on the motorway and motorists are regularly informed about pricing differences between stations through special brochures. Besides, fuels are homogeneous products with very low substitutability and it is established that "because of the almost immediate availability of prices, price competition can lead to a rapid adjustment of competitors".

The European Commission expressed concern about the range of possible pricing policies for a firm with a large number of stations to make the best of these options and consequently weaken isolated competitors in certain highway locations. In a report published on February 9 2000, the Commission indicated that a tacit tariff agreement between the various firms present on the highway was suspected before the merger. In addition, the Commission was worried that such a tariff agreement could still be easy to conclude after the merger took place.

On the other hand, research has proved (be it in the cases of Exxon/Mobil or TotalFina/Elf or in the later decisions issued by the *Conseil de la Concurrence*[1] in 2003) that fuel prices on motorways are far higher than those implemented outside the motorway. The European Commission report concluded that the price of fuel reflected a tacit agreement between the firms on the motorways and that such

1 French Competition Authority. Since March 2009, the *Autorité de la concurrence* has replaced the *Conseil de la concurrence*.

an agreement would be intensified if the merger took place. However, the Commission authorized this operation on the condition that the new firm TotalFina/Elf sold a number of its stations to its competitors. This precaution was not enough to avoid anti-competitive practices on motorways. In a decision issued in 2003, the French Competition Authority sanctioned four oil firms (TotalFinaElf, Shell, BP and Esso) for having agreed on the price of fuel sold at motorway petrol stations.

The underlying idea here is that if the new multi-station entity implemented a potentially aggressive and spatially differentiated pricing policy, this could force reticent isolated independent stations to accept a price agreement. The dominant firm resulting from the merger could eventually threaten the other players with a price war that could completely exclude them or force them to be absorbed by the multi-station. Despite these potential threats, the European Commission authorized the operation on condition that the newly formed entity sold some of its retail stations to competitors. Decision No. C 2000-363 confirmed the following apprehensions:

– In virtue of the simultaneous existence of dominant and multi-station entities, both firms may choose not to set a standard, for fear that this may encourage collusion in motorways.

– Multi-station firms could be tempted to implement predatory strategies against the weakest single-station firms, especially if these are geographically isolated and surrounded by stations of the dominant firm.

As a consequence, instead of doing it against an isolated station, a multi-store firm could circumscribe its price war only to the two stations belonging to its own group and placed immediately adjacent to the competitor. As a matter of fact, Article 219 from the Commission's report explicitly states:

> "The fact that there are sometimes two TotalFina/Elf stations adjacent to one another and that some service stations are caught between two TotalFine/Elf service stations would allow the latter to target any reprisals without this having an effect on other competitors. The

> example of the prices charged by the Leclerc service station illustrates that one station has a direct impact on the prices charged by the two stations immediately next to it and particularly on the station which follows it. So if a competitor decided to step up price competition, it could not be sure that others would follow and would run the risk of seeing TotalFina/Elf carry out selective reprisals against a substantial proportion of its service stations. Given the size of TotalFina/Elf compared with that of each of its competitors [...], the costs of a price war would be unevenly distributed in relation to the cash flows of the motorway service stations".

Thus, the existence of two TotalFina/Elf stations surrounding a specific competing petrol station could enable the multi-store to take reprisals without having a negative impact either on further competitors or on other stations belonging to the group. The Commission's report points out that a geographically targeted price war can be confined to the single-target segment without generating a widespread reaction on all channels. As the report reveals, TotalFina/Elf could carry out selective retaliation and, given its size, absorb the costs of a price war because of the other stations in its own chain.

One of the major concerns of the Commission is the ease that such a configuration offers the multi-station, not only of coordinating tariffs within its range of petrol stations, but fundamentally of carteling against its competitors. The assumption is the following: if independent competitors or those firms in possession of few stations were insensitive or reticent to cartel offers from the multi-station firm, reprisals by the latter would be greatly facilitated by this configuration. For the Commission, it is essential to guarantee that a single firm will not have the possibility of geographically isolating a competing station.

The French Competition Authority followed these criteria on its decision of April 16, 2004 (Opinion No. 04-A-06). In fact, the authority suggested that:

> "…different brands should be distributed evenly along road networks. Situations to be avoided are, for example, that the same trademark controls successive stations on the same path or that a new incomer settles between the stations of a dominant operator".

The problems entailed by this decision particularly concern the importance of keeping an acceptable level of competition in a spatial setting where multi-station firms tend to adopt price policies that rationally adapt to the local competition conditions of their own petrol stations. During the analysis of this study case, we will see that strategic reflection applies not only to the firms involved, but also to authority on competition. On a similar note, we will focus upon the ways in which game theory may contribute to clarify and deepen the boundaries of this question.

6.3. Strategic management questions

A scrupulous examination of the facts related to this case study and of the treatment it received from the European Commission and the Competition Authority is conducive to a number of more general questions relevant to strategic management issues. Among these questions, we may ponder the following:

– In terms of pricing policy and price coordination, what are the strategic advantages for a multi-station, multi-store or multi-product firm compared to a single station or a mono-product firm? How should the multi-store strategically affect the prices of each station or store in a function of local competition?

– Does the possession of such types of store portfolios or stations affect the functioning of markets and competition? In the long term, does it facilitate anti-competitive practices? What would the pricing strategy of such a firm be like if it wished to settle tacit collusion in the industry? What kind of strategy should it enforce in order to defeat competitors?

These questions ultimately point to the way in which a firm rationally conceives spatial segmentation strategies as well as the consequences that such strategies may engender in the area of competition policies. The two components of the problem concern not only business strategists but also the public regulator.

Let us try to visualize and give substance to these problems in a very schematic way. Figure 6.1 shows a motorway and assumes that there is merely one multi-station firm *M* (owning stations 1, …, *j and j* + 1, …, *m*), facing a single-station business venture represented by an independent station *I*.

We will call "external competition" those competitors to the extension of *M'*s stores who do not belong to *M,* that is to say, independent mono-station *I* and the competitors in 0 and 1 (that is to say, the last available stations in town before entering the motorway).

The question that arises is whether cartelization (price coordination) between firm *M* and *I* is feasible and, if so, whether it can be done in a "friendly" way, that is to say, by mutual consent between independent stations *I* and *M*. At the same time, this issue can be divided into several sub-questions:

Q1 – If firm *M* suggests an agreement on the price to its isolated competitor *I* (with a price proposal to be fixed), does the latter find any advantage in accepting this proposal?

Q2 – In the event that the competitor has no advantage in accepting *M'*s original proposal, would firm *M* have the possibility of wielding a price war threat in order to force it to accept the proposal?

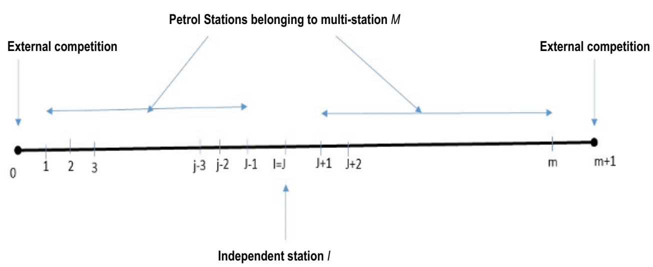


Figure 6.1. *Petrol stations on the motorway*

The idea is that if firm *M* owns a chain of adjacent stations 1, … $j-1$, then $j+1$ until *m*, it can threaten any station that "breaks" the *connection* between the range of *M's stations*. In other words, independent station (called *I*) located at *j* is deprived from the possibility of setting "normal", out-of-competition prices, at $j-1$ and $j+1$, in such a way that station *I* ends up strongly weakened and even deficient. Such a price system would constitute evidence of unfair competition in the sense that firm *M* could adjust prices so as to intentionally put station *I* into a deficit situation. Such a price combination may even be below the average cost of operating stations $j-1$ and $j+1$, that is, *M* may be implementing a dumping policy or what is called "limit price" in industrial economy. Stations $j-1$ and $j+1$ could be deficient without affecting the overall profit of multi-station *M*. The deficits of stations $j-1$ and $j+1$ could be compensated for by the other stations in the range of *M*.

Is such a local limit price strategy always feasible? Can the firm really find an advantage in implementing this strategy instead of fair competition? The answer is not obvious and requires that we compare the effects of both options on the profits obtained by each of the stations in the range held by the firm *M*.

The following game formalizes the problem we are studying.

6.4. The game

We can formalize the previous problem by using a sequential game, as described in Figure 6.2. Firm *M* suggests cartelization to an independent competitor *I*. During the first stage of the game, independent station *I* has to decide whether it accepts the proposal or rejects it. If it accepts, then a cartel is set up on the market. If it rejects the cartel proposal, firm *M* may decide either to react "normally", by displaying fair competition prices, or to engage in reprisals, namely by means of a price war against competitor *I*. The sequential game is shown in the following Figure 6.2.

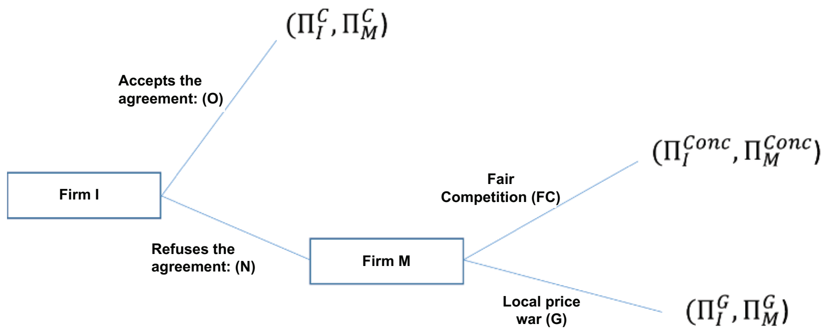


Figure 6.2. *Representation of the sequential game*

Let us now pay closer attention to the process of cartelization between *M* and *I*. The cartel agreement is for firm *M* to offer station *I* a price vector $(p_1, p_2, \ldots, p_I, \ldots, p_m)$ to be assigned to its establishment or more simply, a price p_I to be displayed at its station. Logically, the price that is allocated to station *I* within the framework of cartelization must not only serve the interests of the latter (particularly because firm *M* is dominant), but also contribute to the overall profit aggregate of firm *M*.

What would a price war strategy initiated by multi-station *M* look like in a case in which firm *I* refused to cooperate? If the independent station is placed at location *j*, $1 < j < m$, it is assumed that firm *M* may possibly assign sufficiently low prices to stations $j - 1$ and $j + 1$ belonging to it, so as to reduce station *I*'s profits until these become negative or cancelled. Since this action constitutes an intimidation from firm *M* to *I*, we consider that the threat should be relatively extreme and we assume, in order to set the ideas, that the prices displayed in stations $j - 1$ and $j + 1$ should approach limit prices (what would turn *I*'s profits null).

As a consequence, if *I* refused to accept price coordination, action (G) from firm *M* could be read by *I* as a threat. For motorway carteling to emerge at the perfect equilibrium of the previous game, threat (G) must be credible. Such a threat is credible if it is the best response that firm *M* can offer to the decision to refuse cartelization, in other words, if $\Pi_M^G > \Pi_M^{Conc}$. By definition, if the threat is credible, *it will be executed de-facto in case of denial of cartelization by I and will not be executed at the perfect equilibrium of the game*. Then, if $\Pi_M^G > \Pi_M^{Conc}$, firm *I* will accept the cartel and price coordination will be effective in the industry. However, if $\Pi_M^G < \Pi_M^{Conc}$, the threat of retaliation is not credible and cartelization does not take place, firm *I* will then reject *M*'s proposal.

If the threat is not credible, it is still possible for the cartel to emerge, for the simple reason that what is offered to firm *I* as a price of collusion leads to better profits than those the firm could obtain in the framework of fair competition: $\Pi_I^C > \Pi_I^{Conc}$.

Let us summarize: cartelization emerges at the perfect equilibrium of the game in two cases:

– *Case 1*: when the collusion price suggested by firm *M* to *I* improves the profit of *I* compared to the situation of fair competition;

– *Case 2*: when the price of collusion does not significantly improve *I*'s profits but the threat of reprisals issued by *M* in case of cartelization refusal is credible.

Are there factors in the business environment that may favor one type of equilibrium more than the other (case 1/case 2)?

6.5. Price structure in the event of collusion

What price vector should be allocated to the different stations of firm *M* for this to obtain the maximum profit? This is a complex question. A study based on a model of industrial economics proposed by [GIR 03] gives some strategic elements of reflection that may be interesting to explore in this section.

[GIR 03] suggest analyzing the optimal pricing policy chosen by multi-product firms with the intention of exploiting how to position their range of products in relation to those of the competitor. The authors assume that the overall profit of the multi-product enterprise does not uniquely depend on the size of the firm's product portfolio (number of products, number of stores, stations, etc.), but also on its "components" or, more precisely, on the substitutability of the portfolio's products among each other and in relation to the products of the external competition.

If we apply this logic to the previous case study (petrol stations), we can affirm that the aggregate profit of firm *M* depends on the geographical positioning of its stations on motorways, as well as on the distance between stations owned by firm *M* and its external competitors. We will denominate the continuous chain of adjacent stations that is not "broken" by a competitor a "connected chain". In this way, it appears that the number of related channels in *M*'s portfolio is important to judge the potentialities of a firm to dominate the market.

In order to account for the effects of spatial competition, [GIR 03] sustain their concepts on the basis of a well-known model in industrial economics: the Salop horizontal differentiation model [SAL 79].

The original model by Hotelling [HOT 29] follows a number of hypotheses. First, it assumes the presence of a linear city in which consumers are uniformly localized. Two shops selling the same product wish to settle there and must choose their location in the city simultaneously. After deciding on their location, they must choose their price. Each consumer must buy a single unit of product and must choose in which store this item will be bought. In order to decide in which store he or she will acquire the product, a consumer located somewhere in the city simultaneously observes the price displayed by each store and the distance that separates him or her from each sales point. Besides, consumers consider that the actual price they are required to pay does not exclusively refer to the price of the product but is represented by the sum of that price and the "cost of transportation" induced by the distance to each store.

Consumers located between the two stores compare this total cost, when they choose to buy from one store or the other, and opt for the one that costs them the least. By a calculation procedure, which determines the location of the so-called indifferent consumer, the market share of the two stores can be determined for any two prices displayed by the stores: the market share of the first store is composed by all consumers located from the left end of the city until the location of the indifferent consumer, whereas the market share of the other store corresponds to the consumers located between the indifferent consumer and the right end of the city. Having determined these market shares, we are now capable of describing the profits of both stores and of determining when there is a Nash's equilibrium in price for the second stage of the game. The Backward Induction procedure continues replacing equilibrium prices in the profits, which reveals profit expressions that depend solely on the location of the stores, which had to be decided in the first place. Then, we only need to determine the equilibrium locations for the first stage. Hotelling's model can be extended to the case where there are not two shops but $n > 2$ stores, as in the case of the problem of the motorway we are analyzing. There is also a variant to this linear model that is frequently used. Proposed by [SAL 79], it is a question of considering a circular and non-linear city. The general calculation procedure does not change even if some technical elements associated with this model (which we will not detail here) advocate for the use of this version in certain cases.

Box 6.1. *Spatial differentiation – Hotelling model [HOT 29]*

By relying on this model (Box 6.1), the authors reflect upon the benefits that a firm can derive from having a related line of products. These advantages are directly linked to the interesting possibilities offered by such a related line in terms of tariff coordination. The pricing policy of the multi-product firm can be enhanced by making each line product play a specific role, which will depend on its position in relation to external competition.

Figure 6.3 illustrates this thesis. It shows how prices should be affected in the (related) portfolio of the firm[2]. The products of the firm's most extreme (or "peripheral") related line, closest to external competition, display the lowest prices. On the other hand, the central establishments of the line, which are placed further away from competition, display the highest prices. Despite a policy of low prices, the settings closest to competition may unexpectedly get the highest profits in the industry because they obtain the largest market share (extracted not only from the competitor but also from the neighboring

2 This price configuration is endogenized by determining the price vector that maximizes the total profit of the firm, which can be defined as the sum of the profits obtained by all the products of the chain (product portfolio).

station of the same firm). Thus, the "sold-off" product of the portfolio is the one that will contribute the most benefits to the firm. At the same time, the firm's "ante-peripheral" product (the most substitutable or nearest the peripheral product) will act as a "shield" for the other products of the enterprise but get the lowest profit. With an ante-peripheral location, the firm has the strategic capacity to contain the (relative) price war against external competition, the only segment of the market where its power is really threatened (at the periphery of its product line). By "sacrificing" ante-peripheral products, prices on other segments (those that are far from the competition zone) can be substantially increased.

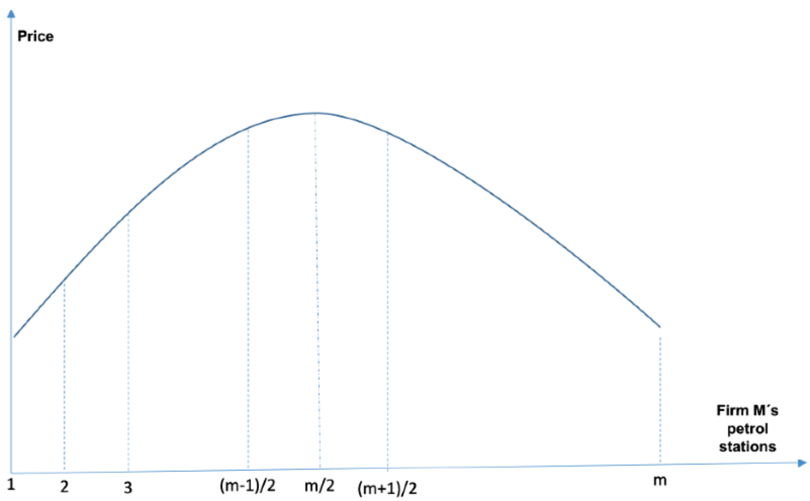


Figure 6.3. *Pricing policy of the multi-station firm*

In summary, this pricing policy enables the distribution of specific roles for each product of the portfolio. The role of the peripheral products of a related component is to tear out the largest possible market share from external competitors. The role of ante-peripheral establishments is to protect the domestic establishments of the product line and to absorb the shocks of competition. This is expressed by a relative loss of market share for the benefit of a neighbor (after all, the peripheral product also belongs to *M*'s portfolio). Protected from the effects of a price warfare against external competitors, domestic establishments enjoy considerable market power over a captive clientele.

The thesis supported by [GIR 03] also shows that a "related" portfolio generates greater payoffs than a "non-related" portfolio. Moreover, the authors suggest that one of the corporate objectives should be to attain the widest possible "connectedness" of products. Moreover, a portfolio composed of a single connected line yields greater profits than a portfolio of several related lines.

Now, let us go back to Q1 from section 6.3.

– If firm *M* proposes a price agreement to its single competitor *I* (with a price proposal to be fixed), does the latter find any advantage in accepting this proposal?

Let us assume for a moment that firm *M*'s proposal for an agreement with independent station *I* reflects the price allocation proposal described in Figure 6.3, a price structure that maximizes the aggregate profit of both firms, *M* and *I*.

The work of [BEN 15], an extension of [GIR 03] research, publishes a number of results concerning the adhesion to multi-station *M*'s cartelization project. We quote some of the results of this study:

R1 – When firm *M* has a relatively small number of stations (relatively small portfolio), the isolated station *I* always accepts carteling, independently of its location on the motorway[3].

R2 – When firm *M* has a relatively large number of stations, the isolated station may not accept the price that *M* proposes, in other words, the cartelization offer. Its decision will mainly depend on its location on the highway.

3 We do not analyze this point in detail, but we must nonetheless mention that the authors have calculated the profits obtained by *I* when it belongs to the line (accepting to display the price suggested by *M*) and the profit *I* would obtain if it were a direct competitor of *M* and freely chose its price.

In a sense, we discover that there exists a critical portfolio size where a single location of *I* could compromise the feasibility of cartelization: this corresponds to the ante-peripheral location (2 and $m - 1$). If the isolated station *I* is located there, it will not accept the price offered to it. And we can understand why. This location is the one that will be used by the firm to guarantee the maximum aggregate profit (see above).

As the size of the portfolio increases and new locations of *I* emerge, this is likely to pose a problem, because cartelization will be curbed. Let us explore this consequence in a pedagogical way. When the dominant firm is in possession of a sufficiently large number of stations, the first location to pose a problem will be location 2 (and $m - 1$). By increasing the number of *M*'s stations, other locations sequentially follow this increase, and the number of *I* locations that cause problems will naturally follow: location 3, then 4, etc., until we reach the central location, which will be resistant to cartelization only if the size of *M* is large enough (sufficiently large *m*).

To recapitulate (Figure 6.4): when firm *M* has few stations, we may assume that its offer will always be accepted by the isolated station and cartelization will become inevitable. It is only when firm M holds a sufficiently large number of stations that station *I* can be tempted to refuse cartelization. The closer station *I* is to external competition, the greater the incentive to refuse cartelization. When the station is located at the center of *M*'s connected line, it will probably accept the project (unless, as we have previously discussed, the number of *M*'s stations is really large).

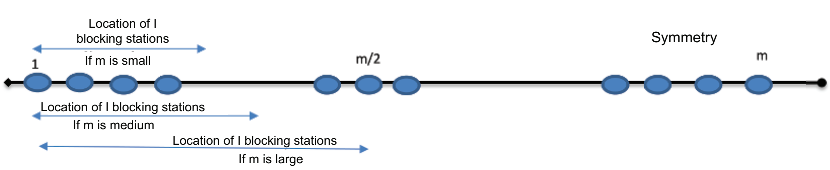


Figure 6.4. *Location of the independent station that engenders the refusal of cartelization*

6.6. Price war threat and game equilibrium

Under the conditions mentioned earlier, when station I refuses cartelization, dominant firm M can wield its power to force the competitor and threaten it with an aggressive pricing policy. This is basically what the report of the Committee presented previously suggests.

The strategy of threatening single-station I with a local price war must be based on the existence of two prices, $\bar{p}_n$ and $\bar{p}_{n+2}$, that M can assign to stations n and $n + 1$, in such a way that even if I responded at its best to $\bar{p}_n$ and $\bar{p}_{n+2}$, it would get zero profit. The execution of such a threat implies that firm M abandons the "normal" competition policy, which tends to allocate prices that respond positively to the firm's overall interest (at least in the short term) and that maximizes its aggregate profit. Firm M must relinquish such a policy in favor of another one that injures and weakens its competitor. M will not seek the policy that maximizes its aggregate profit, but the one that maximizes its profits under the constraint of weakening the competitor.

It is an unfaithful policy that generates a cost to the one who puts it in practice. The cost corresponds to the fact of not aligning the competition price, which should be – according to our game theory terminology – the best reaction to the price displayed by the competitor. This is not the case. Prices $\bar{p}_n$ and $\bar{p}_{n+2}$ are aligned to induce a minimum payoff for I. They are aligned following a certain strategic logic: the anticipation that if I gives its best possible response to $\bar{p}_n$ and $\bar{p}_{n+2}$, it is using its best answer to these two price limits, and obtains zero profit. With $\bar{p}_n$ and $\bar{p}_{n+2}$, firm M oscillates from a logic of fair competition to a logic of unfair competition.

Let us now discuss the feasibility of such an anti-competitive strategy. In the literature of industrial economics, it is a known fact that in a case of competition between two mono-product firms (e.g. that each firm owns a single station) with identical characteristics, one of the two firms will never benefit from applying a limit price policy with the intention of putting the other firm in difficulty. Instead, it will always prefer fair competition. A single exception to this rule is if the game takes place over time and the firm using such a strategy anticipates that its competitor will exit the market in the following period or a short time later. In this case, it will be able to recover monopoly profits in the mid-term or the longer term that could compensate for the loss associated with the anti-competitive strategy. In case of a one-shot game, the payoffs are limited to those obtained that day, the payoffs to which the firm renounces by not resorting to a fair competition strategy will never be compensated.

In the case of a multi-station firm, beyond the local war prices $\bar{p}_n$ and $\bar{p}_{n+2}$, the firm has to set a pricing system for all the other stations that enable it to maximize its aggregate profit. Despite this supplementary flexibility regarding a mono-station firm, the general result stated previously does not change if the game takes place over a single period: there is no reason for the pricing system allotted to *M'*s network of petrol stations and involving limit prices to be conducive to better profits than those in a context of fair competition *unless the system associated with the limit price itself emerges as the best possible (in the sense of the Nash equilibrium) in fair competition*. It is more likely for this type of exception to occur in a multi-product context than in a single-product context. However, we can assert that the threat of retaliation often tends not to be credible in the case of a multi-station firm, unless the companies are placed in a context where the game is repeated over time, and from a certain moment onward, the isolated competitor leaves the market and is eventually bought out by the multi-station firm. A work by [BEN 15], which builds up on the ideas of [GIR 03], shows this result.

Then, it follows that if the previous game is a one-shot game, the cartel can only emerge at the perfect equilibrium of the game if and only if firm *I* accepts the price agreement from the first stage of the game. For this, the suggested price for carteling must provide firm *I* with the perspective of a better profit than the one it could reap from playing an uncooperative game of fair competition. The work of [BEN 15] shows that the profits obtained by firm *I*, if it decides to cooperate, depends in fact on the station's position in the motorway or, more generally, on the loss that it inflicts on firm *M* by adopting a non-cooperative behavior instead of putting itself at the service of the collusion pricing policy that *M* may suggest and whose configuration is shown in Figure 6.4.

6.7 Game equilibrium within a time horizon

In the previous sections, we focused on the fact that a threat of retaliation against the isolated competitor could only be credible if both competitors (the multi-station firm and the isolated firm) anticipated that the reprisal would lead to the expulsion of the isolated competitor. The temporal dimension is still the only possibility that can lead to the emergence of cartelization, even in the case where an isolated competitor is not interested in such an agreement. In this section, we explore the idea that temporality is a necessary but not sufficient condition.

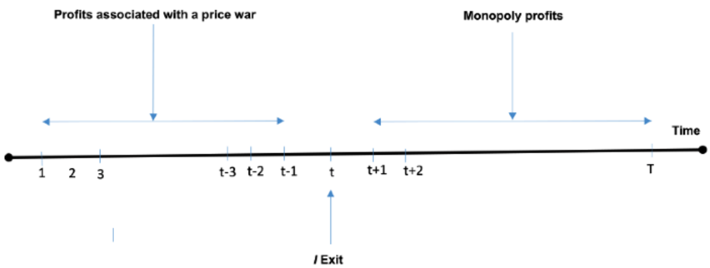


Figure 6.5. *Anti-competition policy from a time-oriented perspective*

Figure 6.5 shows the distribution of profits of the multi-station over a given time horizon, in the case it decides to apply an aggressive price policy to independent station *I*. On periods 1 to *t*, the multi-station obtains a relatively low profit because it is obliged to lower its prices in order to, at least, cancel the profits of station *I*. Faced with the war that the multi-station firm has launched, the station can financially resist a situation of no profit or deficit for a maximum of *t* periods, at the end of which it is forced to leave the market. When it reaches period $t + 1$, the multi-station firm finds itself in a monopoly position until a *T* period, which is the time horizon in which the firm projects itself.

In this case station *I* refuses to coordinate its prices in view of cartelization (according to the logics of the previous section), the multi-station always threatens this station to give it a price war. The only change here is that in order to evaluate the credibility of the threat, via the difference of $\Pi_M^G - \Pi_M^{Conc}$, the calculation must take the time dimension into consideration, particularly (Figure 6.5) what it obtains if it engages in a price war policy against station *I*, Π_M^G for each period from 1 to *t* and Π_M^{Monop} for each of the periods between *t* + 1 and *T*. The profits that firm *M* obtains from implementing an aggressive policy equal the sum of all these intertemporal profits.

Since the time horizon may be longer or shorter, it is necessary to also take into account possible monetary depreciation and to update the payoff *M* obtains over this time horizon by setting $\partial, 0 < \partial \leq 1$, the discount rate. As a consequence, the total “war” profit of *M* over a time horizon T should be translated as:

$$\Pi_T^G = \sum_1^t \partial^{t-1}\, \Pi_M^G + \sum_{t+1}^T \partial^{t-1}\, \Pi_M^{Monop}$$

The threat of war of *M* prices is credible if this profit is better than the one *M* could obtain by merely applying a competitive price over all these periods. Here, the profit of intertemporal competition also changes because, due to the discount rate, it equals the weighted sum of all competitive profits Π_M^{Conc} obtained over periods 1 to *T*. This intertemporal profit of competition should be written as follows:

$$\Pi_T^{Conc} = \sum_1^T \partial^{t-1}\, \Pi_M^{Conc}$$

The threat of war is credible if and only if $\Pi_T^G - \Pi_T^{Conc} > 0$, that is to say:

$$\Delta = \sum_1^t \partial^{t-1} (\Pi_M^G - \Pi_M^{Conc}) + \sum_{t+1}^T \partial^{t-1} (\Pi_M^{Monop} - \Pi_M^{Conc}) > 0$$

The difference whose sign determines the implementation of the price war policy depends on the profits obtained over each period and the value of parameters $\partial, \mathrm{t}, \mathrm{T}$: $\Delta \equiv \Delta\left(\partial, \mathrm{t}, \mathrm{T}, \Pi_M^G, \Pi_M^{Conc}, \Pi_M^{Monop}\right)$.

This differential can be written in a simpler way:

$\Delta = \Delta_{MC} \sum_{t+1}^{T} \partial^{t-1} - \Delta_{CG} \sum_{1}^{t} \partial^{t-1}$, where $\Delta_{MC} = (\Pi_M^{Monop} - \Pi_M^{Conc})$ denotes the differential of monopoly and competition profit (over a certain period) and $\Delta_{CG} = (\Pi_M^{Conc} - \Pi_M^{G})$ denotes the differential between competition profit and war profit (over a period). Mathematically, in the expression of Δ, we may recognize two sums of geometric sequences of reason ∂, which we can illustrate by a simple expression. In this way, this difference is simply written as:

$$\Delta \equiv \Delta(\partial, \mathrm{t}, \mathrm{T}, \Delta_{MC}, \Delta_{CG}) = \frac{1}{1-\partial}[\Delta_{MC}\,(\partial^t - \partial^T) - \Delta_{CG}\,(1 - \partial^t)]$$

From this simpler expression of Δ, we can easily deduce the favorable (or sufficient) conditions for the firm to engage in a price war if station *I* refuses coordination with *M*. We provide these conditions bearing in mind that each of them must be considered, all other things being equal. In other words, each of the conditions given in the following is given with reference to the variation of a parameter of Δ, while the other parameters remain fixed. The conditions are the following:

C1 – *A sufficiently large differential between monopoly profit and competitive profit (over a period).* When monopoly profit, that is to say, the profit obtained by *M* after the eviction of *I*, is largely above competition profit, this acts as an encouragement to practice a price war for a simple reason: even if *M* loses during war periods (Δ_{CG} differential), it can hope to compensate this loss during the periods when it acts alone on the market. What do we refer to when we speak of an important differential between monopoly profit and competitive profit? This means that the competitive profit that can be obtained by *M* after a fair confrontation with an independent station is relatively low given station *I*'s location. In fact, the closer the location of station *I* is to the "center" of range 1, ..., *M* of *M*, the greater the impact that the competition of *I* will have on the profits of *M* [HAM 09]. The closer the independent station is to the center of the highway (or to the center of the range of *M* stations), the more costly will be the competition that *I* brandishes against *M* and the more credible will become the price war[4].

C2 – *A relatively small differential between competition profit and war profit (over a period).* This factor refers to the shortfall of firm *M* during the periods when it renounces competition to practice a price war against the independent station. If the shortfall is relatively low, it will be easier to compensate because of what the firm will be able to earn in subsequent periods when it becomes alone on the market (due to the fact that station *I* has been forced to leave the industry). The fact that this differential profit is low can account for two different realities: either the war profit obtained by *M* is not too low (scenario H1) or the profit from competition is relatively high (scenario H2). Scenario H1 can explained either by the (exogenous) fragility of station *I*, whose profit can be lowered (to a zero level) without much effort from *M* (by lowering the price of fair competition) or because of a good compensation for the local loss of profit due to the war that *M* is carrying out against *I* on the zone by the profits obtained by the rest of *M*'s stations. Scenarios H1 and H2, which can also be simultaneously verified (see C1), are dependent on the location of station *I* within the range of stations on the *M* highway.

C3 – *An early (very short-term) exit of station I.* When the exit horizon is close (low t), and knowing that $\partial \leq 1$, then we have $(\partial^t - \partial^T)$, which is large enough, and a sufficiently low $(1 - \partial^t)$, which can contribute to making the Δ differential positive. The fact that this situation is favorable to the credibility of the threat of war is evident: *M*'s losses due to an aggressive pricing policy (rather than a fair policy) will only be recorded over a short period of time and can be compensated by the monopoly profits that the firm intends to get over a longer period. The moment when station *I* leaves the market depends on its ability to withstand deficits. Its permanence on the market depends on its ability to keep the cash flow during these periods of commercial war. Besides, the relationship with the banks, their trust and support can be decisive. Why? Because in this way, the

4 Firm *M* will not be forced to wield this threat if it is in possession of a reduced portfolio of petrol stations (Figure 6.4): in this case, the closest independent station (*I*) to the center will probably accept the cartelization offer.

independent station can credibly send a signal to firm *M* that the exit deadline will be remote if not unlikely, which will have the effect of making *M'*s war threat not credible: if firm *M* grows and integrates this information (far exit horizon), then Δ will be negative. If it were supported by the banks, station *I* could make the signal sent to firm *M* more credible and defeat the threat issued by *M*.

C4 – *A projection on a very distant horizon (high T).* A commercial activity planned over a relatively long time horizon allows the firm to ensure a compensation for the losses generated by the war carried out against station *I* even when the latter resists such an aggressive policy for a long time. The time horizon can be exogenous and result, for instance, from the passing of a contract between the firms and the highway managers or the public authorities, or from changes in the industrial structure on motorways (e.g. if concessions are granted to new players).

C5 – *A discount rate close to 1.* If the discount rate is close to 1, this means that the profits obtained in the future will depreciate relatively little. Even if the losses to be suffered in the near future are appreciable today and can have an important weight on the profits of *M*, the monopoly profits to be gained in the further future will maintain sufficient value today in order to compensate for them.

As we can appreciate, conditions C1–C5 positively contribute to the credibility of the threat of a price war of firm *M* against isolated station *I*. When one or more of these conditions are verified, and the threat being credible, this will never be carried out at the equilibrium of the extended game we have discussed and the isolated station *I* will accept *M'*s offer of collusion.

6.8. Conclusion

This chapter analyzed the thorny issue of anticompetitive agreements and practices when there is an imbalance of power between firms operating in an industry. Here, the imbalance of market power is associated with the multi-product or mono-product character of the firms involved. The case study of the sale of fuel is particularly interesting. The reports of the various competition supervisory authorities, both at a national (in France in particular) and a supranational level, have recognized the importance of the geographical dimension in the formation of motor fuel prices. As we have mentioned during the presentation of the facts, the European Commission particularly recognized the existence of "chain substitutability on each motorway" between service stations. This idea of chain substitutability, which is essential to the strategic thinking we have suggested, was more explicitly taken up by the *Conseil de la Concurrence*[5] in a 2004 report (no. 04-A-06 of April 16th), which recommended that:

> "... the distribution of different signs along motorway networks be sufficiently balanced, the aim being to prevent the same sign from controlling successive stations on the same route or that a station allocated to a new entrant become isolated between the stations of a dominant operator".

In this way, the Commission and the French Competition Council contemplated the possibility of an agreement between the main firms on the French motorways. The various competition authorities often make reference to the possibility of retaliation that an oil firm could exert against isolated competitors within a chain of adjacent stations belonging to it in the event that the competitors refused to comply with the price coordination suggested by the dominant firm. The findings of the Commission concerning the TotalFina/Elf merger account for this phenomenon in the following terms:

> "The presence of duplicates and stations interspersed between two TotalFina-Elf stations would allow the latter to target retaliatory actions against a competitor without simultaneously affecting the efficiency of other competitors".

From the point of view of strategic analysis, such a strategy on the part of the dominant firm (a "package" that includes an offer of

5 French Competition Council.

cooperation and a threat at the same time) is certainly interesting. We have shown under what conditions, in a competition scenario within a time horizon, such a strategic package could work and the agreement be implemented on the highway.

What is more, beyond the concrete case that we explored in this chapter, the application we suggest makes it possible to grasp the fundamental difference that may exist between (1) the legitimate strategies of multi-product firms rationally exploiting the related character of their range of products and (2) the anticompetitive practices that exploit the advantages of this connection in order to exert pressure on mono-product competitors. In fact, such a structure of brand or product portfolios makes it easier to delineate certain anticompetitive strategies. Given this advantage, can it be used as an explanatory tool for targeted buying and the acquisition strategies of industrial groups? The question remains open and the research papers quoted in this chapter have explored it in greater depth.

7

Application 4: HD-DVD versus Blu-ray

7.1. Introduction: individual strategies and collective dynamics

This chapter is dedicated to the application of the concept of stability of coalitions to a problem that has been largely discussed in the media sector.

The battle that raged in the 2000s between two formats of high-definition (HD) DVD players, HD-DVD versus Blu-ray, is helpful for understanding the concept of coalition in game theory, as well as for better apprehending the strategic implications for the firms involved in the sector, and broadly speaking, for the media and the entertainment industry. As discussed in this chapter, Consumer Electronics Manufacturers (CEM) did not fight this battle alone.

In the field of video and entertainment, this is not the first "format war". In the 1970s, Sony (with Betamax in 1975) and JVC (with VHS in 1976) launched two competing and incompatible standards for video cassettes. When Sony launched its Betamax, the firm was convinced that other manufacturers would recognize the superiority of its technology and abandon their formats in favor of Betamax. But in the end, the first battle for standards in this industry resulted in the definitive exclusion of Betamax from the massive market. For the record, Sony did not stop delivering Betamax tapes until very recently,

Game Theory Approach to Managerial Strategies and Value Creation,
First Edition. Abdelhakim Hammoudi and Nabyla Daidj.

in March 2016, years after the production of video recorders definitely stopped (in 2002, sales having reached a number of 18 million units).

Holding a dominant position until 1990, the VHS was later replaced by a new technological generation, the DVD, and then by HD-DVD players, which incorporated Blu-ray technology. We describe and analyze the main stages of the battle between Blu-ray and HD-DVD.

7.2. Constitution of HD-DVD and Blu-ray consortiums

In the early 2000s, Sony and Toshiba were the initiators of Blu-ray and HD-DVD, respectively. Both groups sought to attract the largest number of participants from both the manufacturers of CEM and content editors (movie studios), who finally made their choice in favor of one or the other DVD player. Some of them even decided to support both formats: HP, Nec, CaNo, Ricoh, Alpine, Fuji, Lenovo, Onkyo, Kenwood, LG and Thomson.

As for Sony, the development of the Blu-ray format followed a more global strategy of the group in a context of technological and industrial convergence, which marked the year 2000 and gave an impulse to firms to integrate vertically. Vertical integration was at the heart of the process of value creation and mainly referred to a long desired convergence. The concept of convergence involves different kinds of contents (audiovisual, films, etc.), multiple networks and distribution channels (cinema, TV, video, Internet) as well as an ample variety of media. As a consequence, “AnyWay, AnyWhere, AnyWhere, AnyDevice” (ATAWAD) and ATAWADAC (ATAWAD + AnyContent) became the slogans of convergence [DAI 11, DAI 15]. Vertical integration reinforced the direct link between content and subscribers, by successfully combining portfolios of content rights (the press, the audiovisual, cinema and music) and multiple distribution networks (cable, Internet, etc.). It was in this context that Sony aimed at becoming a major player in the media and entertainment sector, as well as expanding beyond its core business, represented by consumer electronics equipment. In the 1990s and the 2000s, Sony mainly focused on diversifying its activities and succeeding this “famous” integration of equipment (TV, Smartphones, video game consoles), contents (acquisition of cinema studios) and networks [DAI 13]. Incorporating the Blu-ray DVD player for increasing the sales of the video console PlayStation 3 (PS3) was a key element in this layout and these strategic orientations.

Between 2002 and 2008, the period corresponding to a battle between the two standards, HD-DVD and Blu-ray, was characterized by many changes in the decisions of certain manufacturers and studios on whether to adopt a one or the other format, which led to a climate of uncertainty as to the final outcome. Figure 7.1 provides a simplified diagram of the structure of the two consortiums, where manufacturers and studios are represented upstream and downstream, respectively.

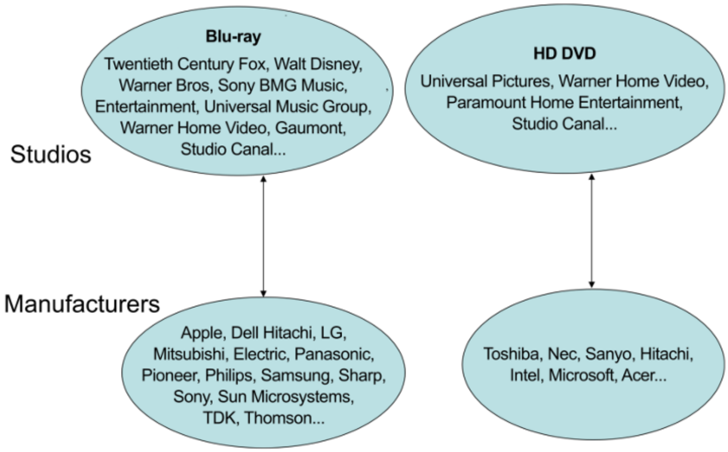


Figure 7.1. *Representation of the different stakeholders at the heart of the battle over high-definition DVD formats*

The consortium led by Toshiba (with Hitachi, Sanyo, Intel and Microsoft) was successful in attracting such studios as Universal Pictures, Paramount and especially Warner Bros, member of the Time Warner group, which was one of the outstanding Hollywood cinema studios at the moment.

At the same time, on "the opposite side", the groupings took place in several stages: in May 2002, the Blu-ray Disc founding group was made up of nine major companies in the CEM sector: Sony, Panasonic, Pioneer, Philips, Thomson, LG Electronics, Hitachi, Sharp, and Samsung Electronics. This alliance was followed by the formation of the BDA (Blu-ray Disc Association) in 2004. Increasingly, more and more companies joined the BDA (more than 70 in 2004).

Between 2004 and 2005, many attempts were made for making both formats converge. We should bear in mind that the two formats were incompatible, both were based on greater technological developments than the DVD and displayed similar technical performances (better visual and sound quality, protection against piracy, etc.). Nevertheless, in May 2005, Toshiba refused the convergence of both formats arguing that its technology was superior and the discussions between Sony and Toshiba came to an end.

Between 2004 and 2007, a series of events and a conjunction of circumstances ultimately led to the abandonment of the standard developed by Toshiba:

– The launch of Sony's PS3 in late 2006 in Japan and the United States (early 2007 in Europe) might have contributed to speeding up the adoption of Blu-ray. From the beginning, Sony had declared it was willing to integrate a Blu-ray player into its video game console.

– In 2004, Sony's acquisition of the Metro-Goldwyn-Mayer (MGM), one of Hollywood's emblematic studios, was a real milestone. Naturally, MGM switched to Blu-ray.

– Two studios, Paramount and Warner Bros, who had committed themselves to maintaining HD-DVD exclusivity, changed their mind in 2005, claiming that films would also be available in Blu-ray format.

– In 2006, while the two rival consortiums could not find a compromise and propose a unique and universal format, Samsung threatened to launch a reader capable of reading DVD, HD-DVD and Blu-ray formats.

– At the beginning of 2008, the commitments toward Toshiba collapsed, with Warner Studios and the American distribution giant Wal-Mart deciding to exclusively support Blu-ray. Warner Bros' decision had a very strong impact and probably accelerated the end of the HD-DVD format. Rumors spread that Toshiba might have tried to convince Warner Bros to remain their customer in exchange for substantial financial compensation, which might also have been true of Paramount and DreamWorks Animation. At that moment, the CEO of Warner Bros Home Entertainment Group, Kevin Tsujihara, is said to have denied this information.

In February 2008, Toshiba announced it would finish the commercialization of readers and recorders as from the end of March. Thus, the battle ended with a victory by Sony.

A decade later, it is interesting to ponder the success of the Blu-ray format (reader and support) with the general public. Nowadays, for a great number of consumers, the question is not so much whether to acquire a Blu-ray player but rather to arbitrate between different modes of video consumption: online (streaming, downloads because of the development of VOD/NVOD[1] and the offer of actors such as Netflix) or via physical media (DVD or Blu-ray). Many agencies and consulting firms have published descending figures regarding the purchase of physical media (films) at an international level:

> "Sales of DVD and Blu-ray Disc titles worldwide topped $18 billion in 2016, down 17% from $21.6 billion in 2015, and are expected to drop to $9.1 billion by 2020, according to new data from Futuresource Consulting. In the United States, the decline was below double digits with disc sales ($5.5 billion) down about 8% from $6 billion in 2015, according to DEG: The Digital Entertainment Group". [GRU 17]

In France, a report by [CEN 17] showed that the DVD was still the preferred medium for film sales, although figures for 2016 showed a decline in the physical video market: –15.8% in value and –8.1% in volume. On the other hand, the supremacy of the DVD partly took place to the detriment of Blu-ray (Table 7.1). The consumer's enthusiasm for a new player incorporating better performing technology, such as that of Blu-ray, was limited. Only a feeble

1 TN: Video on Demand (VoD)/Near Video on Demand (NVoD).

percentage of the population in France chose to adopt Blu-ray equipment. In 2016, Blu-ray barely represented 25% of the turnover of the video industry, against the results of 2015, totaling 24.1%.

	Units (millions)	Evolution (%)	Turnover (M€)	Evolution (%)
DVD	68.28	–9.0	446.70	–16.8
Blu-ray	12.99	–2.7	148.82	–12.7
Total	81.27	–8.1	595.53	–15.8

Source: [CEN 17].

Table 7.1. *Purchase of physical video devices in France in 2016*

7.3. Definition of the game

Let us consider a structure (called S) of a two-format industry, 1 and 2. Upstream, the structure is composed of a number of N identical studios (content providers) and downstream, we find M identical manufacturers (CEM equipments).

The $n, (n \leq N)$ studios having adopted format 1 establish what we call S_1^U set, and the other $N - n$ having adopted format 2 establish what we call S_2^U.

The $m, (m \leq M)$ manufacturers having adopted format 1 compose the S_1^D set, and the other $M - m$ having adopted format 2 compose the S_2^D set.

A C_i consortium refers to a set of S_i^U studios and S_i^D manufacturers having adopted the same format, $C_i = \{S_i^U, S_i^D\}, i \in \{1,2\}$.

The payoff obtained by a studio or a manufacturer results from the profit obtained because of the confrontation of these firms in the final market. The model we suggest does not specifically formalize competition and the implementation of industrial strategies in the final market[2]. Let us suppose that the final payoff of a studio and/or a manufacturer depends, *in fine*, on the (x, y) size of the consortium to which it belongs: $((x, y) = (\text{number of studios, number of manufacturers}))$.

Let us observe that:

$\pi_1(n, m)$ (respectively, $\pi_2(N-n, M-m)$) is the benefit of one studio in S_1^U(respectively, of one studio in S_2^U);

$B_1(n, m)$ (respectively, $(N-n, M-m)$) is the benefit of a manufacturer in S_1^D (respectively, of a manufacturer in S_2^D).

We now put forward two important hypotheses for our analysis that may reflect what we can observe in the sector.

H1: Positive externality of the enlargement of a coalition in a consortium. In a $C_i(x, y), i \in \{1,2\}$ consortium, we have $\frac{\partial \pi_i(x,y)}{\partial y} \geq 0$ and $\frac{\partial B_i(x,y)}{\partial x} \geq 0$.

H2: Trade-off between network effect/competition effect. In a $C_i(x, y)$ consortium, y manufacturers of S_i^Dmay have:

– an interest in increasing their number $\left(\frac{\partial B_i(x,y)}{\partial y} \geq 0\right)$ because an expansion of their coalition attracts new customers;

– an interest not to increase their number so much $\left(\frac{\partial B_i(x,y)}{\partial y} \geq 0\right)$ because competition at the interior of the SiDcoalition of y manufacturers has a strong impact if they are numerous, regarding the created value that has to be shared.

This trade-off between network effect/competition effect is also valid for the S_i^Ucoalition of studios.

2 Such type of microeconomic formalization (yielding information on the exact manner in which the modification of the structure could affect benefits) would certainly need to incorporate the interactions of markets and to specify the nature of the strategies adopted: prices, market share effects, etc.

The battle for DVD highlights the effect that a unilateral upstream or downstream deviation (a format change by a studio or a format change by a manufacturer) might have on the global structure $S = \{S_1^U, S_2^U, S_1^D, S_2^D\}$. It is important to observe that a format change by a manufacturer or a studio may prompt other manufacturers and/or studios to change their formats. These upstream–upstream, downstream–downstream and upstream–downstream interdependencies characterize a certain game typology that is not limited to the media sector.

The game we are going to explore must rigorously reflect the rationality of the decisions made by players (studios and constructors) and help us understand the evolution of the global upstream and downstream structure toward a solution that balances the strategic interactions of the different players involved at all the levels of the chain. Now, let us consider the following sequential game:

First stage: Each studio $i, (i \in \{1,2,\dots,N\})$ chooses one of the two formats: 1 or 2. Decisions are made simultaneously.

Second stage: Each manufacturer $j, (j \in \{1,2,\dots,M\})$ chooses one of the two formats: 1 or 2. Decisions are made simultaneously.

The resolution of such a game is done by *backward induction*. Given $n, (n \leq N)$, for those studios having chosen format 1, we determine the Nash equilibrium for a *static game* where manufacturers simultaneously choose formats 1 or 2 (second stage). At the end of the second stage, we get a stable coalition structure (downstream structure of manufacturers), where no studio has an interest in unilaterally changing coalition (or format). By defining the equilibrium of the second stage (no unilateral deviation from the strategy of adherence to format at the equilibrium point), we encounter once again the criterion of internal and external stability defined in Chapter 3. More precisely:

– $\{S_1^D, S_2^D\}$ structure is internally stable if $B_1(n,m) \geq B_2(N-n, M-m+1)$;

– $\{S_1^D, S_2^D\}$ structure is externally stable if $B_2(N-n, M-m) \geq B_1(n, m+1)$.

Given n (n format 1 studios and $N - n$ format 2), let us suppose that there exists a stable coalition of $m^*, (m^* \leq M)$ manufacturers. Let us pay attention to the case where $0 < m^* < 1$ (internal solution at equilibrium point). m^* is the intersection point of two curves $B_1(n, m)$ and $B_2(N - n, M - m + 1)$ under hypothesis H_1 and H_2. We can infer that function $\Delta B(n, m) = B_1(n, m) - B_2(N - n, M - m + 1)$ acquires positive values for small values of m and negative values for big values of m. Then it is a question of determining the solution for m in the context of the equation $\Delta B(n, m) = 0$. The existence of such a solution or such an amount of downstream equilibrium manufacturers is ensured if there are economic effects that encourage format 2 manufacturers to (unilaterally) endorse format 1 when the latter is relatively "deserted" by manufacturers but, insofar as the coalition "refills", it becomes less and less interesting to join it. This effect (attraction effect of 1 when there are few manufacturers in 1 and the opposite effect when there are relatively too many) is assured under the previous hypothesis H_2. Figure 7.2 provides a representation of a case where the existence of such a stable coalition is guaranteed.

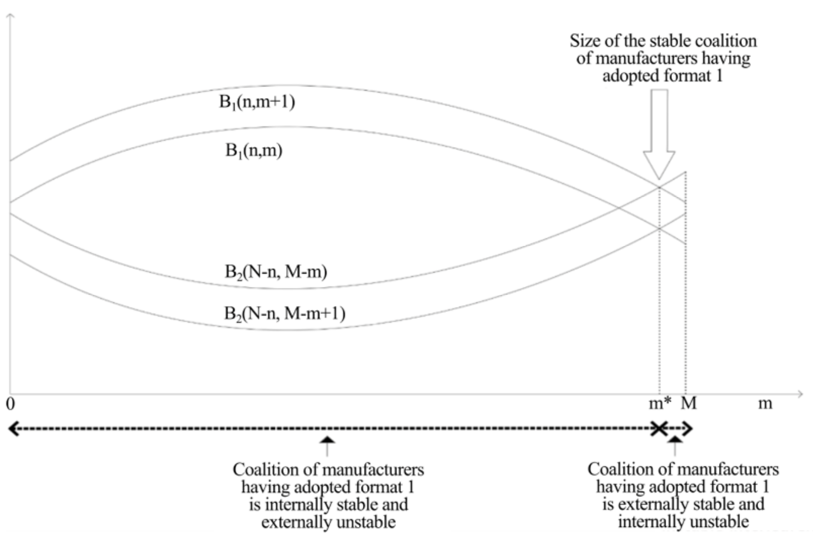


Figure 7.2. *Representation of the game*

Let us consider function $m^*(n)$, which designates the equilibrium size of the second stage of the game for an n number of studios that joined format 1 during the first stage. The complementary model (manufacturers having adopted format 2) of size $M - m^*(n)$ is, *de facto*, a stable coalition. It is reasonable to assume that the size of the coalition of manufacturers adhering to format 1 is increasing as a function of n. In other words, format 1 is likely to attract more manufacturers as the number of studios having endorsed the format increases.

The resolution of the second stage of the game, that is to say, the emergence of the coalition of size $m^*(n)$, is anticipated by the studios that had to decide on their format during the first stage. The size (or function) $m^*(n)$ is injected by each studio in the expression of their benefit (replacement of m by $m^*(n)$). The profit of each studio at the moment when it decides its format at the first stage of the game depends on a single variable: their own decision to adhere and the decision of other studios.

At this second stage, once again we apply the procedure previously used. We calculate the Nash equilibrium associated with the studios' endorsement decisions. If such a balance exists and is internal, this means that there is a stable coalition of studios adopting format 1 (or, equivalently, a stable coalition of studios adopting format 2).

Now, let us suppose that there exists a stable coalition of studios having adopted format 1 and that the size of this coalition is $n^* \in]0, N[$. Following assumptions H_1 and H_2, we may infer the size of n^*, simply by solving the equation $\pi_1\big(n, m^*(n)\big) - \pi_2\big(N - n + 1, M - m^*(n-1)\big) = 0$.

Let us suppose n^*, the solution to this equation, and let us imagine that it is internal. At the outcome of the game, the stable structure of coalitions (stable consortium structure) is simply given by $\left[n^*, m(n^*)\right]$ for consortium 1 and $\left[N - n^*, M - m(n^*)\right]$ for consortium 2.

7.4. Numerical application[3]

In order to better apprehend the resolution process previously mentioned, we are going to consider an example where the different functions of the model are specified.

Let us suppose that the number of studios is $N = 4$ and that the number of manufacturers is $M = 4$.

Now, let us suppose that the created value $V(x, y)$ in consortium $C_i(x, y)$ is given by the following expression:

$$V(x,y) = \sqrt{x} + \sqrt{y}, \qquad \forall (x,y) \in \{0,1,2,3,4\} \times \{0,1,2,3,4\}$$

The payoffs of a manufacturer and of a studio belonging to consortium $C_i(x, y)$ are expressed as:

$$\pi_i(x,y) = \lambda \frac{V(x,y)}{x}; B_i(x,y) = (1-\lambda)\frac{V(x,y)}{y}, \text{ where } \lambda \in [0,1]$$

Parameter λ designates the share in the value created by the consortium between studios (upstream) and manufacturers (downstream).

Let us suppose that the strategic decision of a studio or a manufacturer is 1 if it has chosen format 1 and 2 if it has chosen format 2. For example, the strategies vector (1,1,1,1) indicates that the four studios have chosen format 1. Vector (1,2,1,1) indicates that only one of the four studios has chosen format 2. For the stage where manufacturers have to choose their formats, we will keep the same strategy notation system and in the second phase, we will reason backward regarding the initial structure of studios. In order to solve the game, we have to define $(n, N - n)$ and seek the outcome that corresponds to the strategic behavior of manufacturer adherence at the second stage. Each upstream coalition structure (studio) must then be associated with the matching downstream coalition structure (manufacturers), which emerges at the second stage, when the manufacturers' adhesion game reaches equilibrium.

3 Nacim Nait Mohand (LAMOS, Béjaia University) contributed to this section. We kindly thank him for his participation.

As an example, Table 7.2 shows a fixed structure of upstream studios, as well as the stable structures that we obtain in the second stage of the game, and this, for all possible parameter values.

<table>
<tr><th rowspan="2">Initial studio structure</th><th colspan="3">Possible manufacturer structure and their stability</th><th rowspan="2">Manufacturer final stable structure</th></tr>
<tr><th>Possible structures</th><th>Internally stable?</th><th>Externally stable?</th></tr>
<tr><td>(1,1,1,1)</td><td>(1,1,1,1)</td><td>$(1-\lambda)\frac{\sqrt{4}+\sqrt{4}}{4} \geq (1-\lambda)\frac{\sqrt{0}+\sqrt{1}}{1}$ Yes</td><td>External stability is undefined (all manufacturer are in format 1)</td><td>(1,1,1,1)</td></tr>
<tr><td rowspan="5">(1,1,1,2)</td><td>(1,1,1,1)</td><td>$(1-\lambda)\frac{\sqrt{3}+\sqrt{4}}{4} \geq (1-\lambda)\frac{\sqrt{1}+\sqrt{1}}{1}$ No</td><td>External stability is undefined (all manufacturer are in format 1)</td><td rowspan="5">(1,1,2,2)</td></tr>
<tr><td>(1,1,1,2)</td><td>$(1-\lambda)\frac{\sqrt{3}+\sqrt{3}}{3} \geq (1-\lambda)\frac{\sqrt{1}+\sqrt{2}}{2}$ No</td><td>$(1-\lambda)\frac{\sqrt{1}+\sqrt{1}}{1} \geq (1-\lambda)\frac{\sqrt{3}+\sqrt{4}}{4}$ Yes</td></tr>
<tr><td>(1,1,2,2)</td><td>$(1-\lambda)\frac{\sqrt{3}+\sqrt{2}}{2} \geq (1-\lambda)\frac{\sqrt{1}+\sqrt{3}}{3}$ Yes</td><td>$(1-\lambda)\frac{\sqrt{1}+\sqrt{2}}{2} \geq (1-\lambda)\frac{\sqrt{3}+\sqrt{3}}{3}$ Yes</td></tr>
<tr><td>(1,2,2,2)</td><td>$(1-\lambda)\frac{\sqrt{3}+\sqrt{1}}{1} \geq (1-\lambda)\frac{\sqrt{1}+\sqrt{4}}{4}$ Yes</td><td>$(1-\lambda)\frac{\sqrt{1}+\sqrt{3}}{3} \geq (1-\lambda)\frac{\sqrt{3}+\sqrt{2}}{2}$ No</td></tr>
<tr><td>(2,2,2,2)</td><td>Internal stability is undefined (no manufacturer in format 1)</td><td>$(1-\lambda)\frac{\sqrt{1}+\sqrt{4}}{4} \geq (1-\lambda)\frac{\sqrt{3}+\sqrt{1}}{1}$ No</td></tr>
<tr><td rowspan="4">(1,1,2,2)</td><td>(1,1,1,1)</td><td>$(1-\lambda)\frac{\sqrt{2}+\sqrt{4}}{4} \geq (1-\lambda)\frac{\sqrt{2}+\sqrt{1}}{1}$ No</td><td>External stability is undefined (all manufacturer are in format 1)</td><td rowspan="4">(1,1,2,2)</td></tr>
<tr><td>(1,1,1,2)</td><td>$(1-\lambda)\frac{\sqrt{2}+\sqrt{3}}{3} \geq (1-\lambda)\frac{\sqrt{2}+\sqrt{2}}{2}$ No</td><td>$(1-\lambda)\frac{\sqrt{2}+\sqrt{1}}{1} \geq (1-\lambda)\frac{\sqrt{2}+\sqrt{4}}{4}$ Yes</td></tr>
<tr><td>(1,1,2,2)</td><td>$(1-\lambda)\frac{\sqrt{2}+\sqrt{2}}{2} \geq (1-\lambda)\frac{\sqrt{2}+\sqrt{3}}{3}$ Yes</td><td>$(1-\lambda)\frac{\sqrt{2}+\sqrt{2}}{2} \geq (1-\lambda)\frac{\sqrt{2}+\sqrt{3}}{3}$ Yes</td></tr>
<tr><td>(1,2,2,2)</td><td>$(1-\lambda)\frac{\sqrt{2}+\sqrt{1}}{1} \geq (1-\lambda)\frac{\sqrt{2}+\sqrt{4}}{4}$ Yes</td><td>$(1-\lambda)\frac{\sqrt{2}+\sqrt{3}}{3} \geq (1-\lambda)\frac{\sqrt{2}+\sqrt{2}}{2}$ No</td></tr>
</table>

	(2,2,2,2)	Internal stability is undefined (no manufacturer in format 1)	$(1-\lambda)\frac{\sqrt{2}+\sqrt{4}}{4} \geq (1-\lambda)\frac{\sqrt{2}+\sqrt{1}}{1}$ **No**	
	(1,1,1,1)	$(1-\lambda)\frac{\sqrt{1}+\sqrt{4}}{4} \geq (1-\lambda)\frac{\sqrt{3}+\sqrt{1}}{1}$ **No**	External stability is undefined (all manufacturer are in format 1)	
	(1,1,1,2)	$(1-\lambda)\frac{\sqrt{1}+\sqrt{3}}{3} \geq (1-\lambda)\frac{\sqrt{3}+\sqrt{2}}{2}$ **No**	$(1-\lambda)\frac{\sqrt{3}+\sqrt{1}}{1} \geq (1-\lambda)\frac{\sqrt{1}+\sqrt{4}}{4}$ **Yes**	
(1,2,2,2)	(1,1,2,2)	$(1-\lambda)\frac{\sqrt{1}+\sqrt{2}}{2} \geq (1-\lambda)\frac{\sqrt{3}+\sqrt{3}}{3}$ **Yes**	$(1-\lambda)\frac{\sqrt{3}+\sqrt{2}}{2} \geq (1-\lambda)\frac{\sqrt{1}+\sqrt{3}}{3}$ **Yes**	(1,1,2,2)
	(1,2,2,2)	$(1-\lambda)\frac{\sqrt{1}+\sqrt{1}}{1} \geq (1-\lambda)\frac{\sqrt{3}+\sqrt{4}}{4}$ **Yes**	$(1-\lambda)\frac{\sqrt{3}+\sqrt{3}}{3} \geq (1-\lambda)\frac{\sqrt{1}+\sqrt{2}}{2}$ **No**	
	(2,2,2,2)	Internal stability is undefined (no manufacturer in format 1)	$(1-\lambda)\frac{\sqrt{3}+\sqrt{4}}{4} \geq (1-\lambda)\frac{\sqrt{1}+\sqrt{1}}{1}$ **No**	
(2,2,2,2)	(2,2,2,2)	Internal stability is undefined (no manufacturer in format 1)	$(1-\lambda)\frac{\sqrt{4}+\sqrt{4}}{4} \geq (1-\lambda)\frac{\sqrt{0}+\sqrt{1}}{1}$ **Yes**	(2,2,2,2)

Table 7.2. *Determination of upstream stable structures according to given downstream structure*

In function of n (regarding $N-n$), each studio can anticipate the number of studios having chosen format 1 (with regard to the number of studios having chosen format 2), the number of $m^*(n)$ manufacturers that will choose format 1 and those (respectively, $m^*(N-n)$ that will choose format 2:

$$m^*(n) = \begin{cases} 0, & if\ n = 0; \\ 2, & \text{if } n \in \{1,2,3\}; \\ 4, & \text{if } n = 0; \end{cases}$$

Let us summarize the results obtained:

– When all the studios choose the same format, all manufacturers choose this format and the downstream structure is stable.

– When some studios choose a format and others choose the second format, whatever their distribution on the two formats, manufacturers become symmetrically distributed between the two formats (two manufacturers per format) and the downstream structure is stable.

These results constitute a stage in the search for stability in the global structure. At this point, we must check whether there exists an incentive for the studios to deviate unilaterally from each of the upstream initial structures introduced in the previous table. When a studio deviates, another coalition of manufacturers can be set up, which is different from that prevailing before the deviation takes place. In order to determine whether it is beneficial to deviate from the initial structure (first column of Table 7.2), we must compare:

– the profit that it obtains while remaining in this structure, bearing in mind that the downstream stable structure corresponds to the second column of Table 7.2;

– the profit that it obtains when it deviates from the initial structure (first column of Table 7.2), knowing that, if necessary, another stable structure of manufacturers can be set up. This structure is anticipated by the studio (last column of Table 7.2).

Applying this method, in Table 7.3, we will test the profitability of the unilateral deviation of studios.

Evolution of the structure of the stable coalition of manufacturers after studio deviations				
Initial studio structures	Associated manufacturer stable coalition	Final manufacturer stable coalition (after unilateral movement of one studio)	Gain derived from deviation	Result
(1,1,1,1)	(1,1,1,1)	(1,1,1,1) when a studio leaves the format 1	$\lambda\frac{\sqrt{4}+\sqrt{4}}{4} \geq \lambda\frac{\sqrt{1}+\sqrt{2}}{1}$ **No**	Unstable
(1,1,1,2)	(1,1,2,2)	(1,1,1,1) one studio joins the format 1 (1,1,2,2) when a studio leaves the format 1	$\lambda\frac{\sqrt{3}+\sqrt{2}}{3} \geq \lambda\frac{\sqrt{2}+\sqrt{2}}{2}$ **No** $\lambda\frac{\sqrt{1}+\sqrt{2}}{1} \geq \lambda\frac{\sqrt{4}+\sqrt{4}}{4}$ **Yes**	Unstable

(1,1,2,2)	(1,1,2,2)	(1,1,2,2) when a studio joins the format 1 (1,1,2,2) when a studio leaves the format 1	$\lambda\frac{\sqrt{2}+\sqrt{2}}{2} \geq \lambda\frac{\sqrt{3}+\sqrt{2}}{3}$ **Yes** $\lambda\frac{\sqrt{2}+\sqrt{2}}{2} \geq \lambda\frac{\sqrt{3}+\sqrt{2}}{3}$ **Yes**	Stable
(1,2,2,2)	(1,1,2,2)	(2,2,2,2) when a studio leaves the format 1 (1,1,2,2) when a studio joins the format 1	$\lambda\frac{\sqrt{1}+\sqrt{2}}{1} \geq \lambda\frac{\sqrt{3}+\sqrt{4}}{4}$ **Yes** $\lambda\frac{\sqrt{3}+\sqrt{2}}{3} \geq \lambda\frac{\sqrt{2}+\sqrt{2}}{2}$ **No**	Unstable
(2,2,2,2)	(2,2,2,2)	(1,1,2,2) when a studio joins the format 1	$\lambda\frac{\sqrt{4}+\sqrt{4}}{4} \geq \lambda\frac{\sqrt{1}+\sqrt{2}}{1}$ **No**	Unstable

Table 7.3. *Determination of the upstream stable structure and of the global stable structure*

The results in Table 7.3 show that the global stable structure is the symmetric structure [(1,1,2,2), (1,1,2,2)] composed of two format 1 studios and two format 2 studios, as well as two format 1 manufacturers and two format 2 manufacturers.

7.5. Conclusion

The concepts of endogenous coalition formation can be applied to a variety of real economic problems. The example we suggested in this chapter is an illustration of this. It is particularly relevant and useful because, beyond the lessons it brings to the understanding of the strategic exploitation related to the case studied (namely the battle between HD-DVD versus Blu-ray), it provides enlightening elements with regard to the concepts themselves (coalition formation).

Particularly, it reveals – and it is important to remember this – that the notion of coalition does not systematically refer to cooperation between players *stricto sensu*. In the case of the HD-DVD/Blu-ray battle, *a posteriori*, there is no cooperative inclination whatsoever between the members of the coalitions (e.g. HD-DVD manufacturers), not to mention coordination around any economic variable. The members of a coalition or an upstream/downstream structure do not share a project in common to be carried out for the sake of the coalition.

How is it possible to associate the formation of a studio coalition with a coordination problem? In the specific case of HD-DVD/Blu-ray, if there is coordination on the decision to "endorse" a format, it can only be implicit or done ex post, once the coalition has been formed. Let us imagine that the studios that choose the same format have reached an agreement *ex ante*, within the framework of a concerted and coordinated action. If the group of studios that envisions such a concerted action is not the same as the stable coalition obtained at the equilibrium of the embryonic game, this action will be doomed to failure. It will fail either by unilateral individual defection or because it is inevitably destined to expand. The nuance comes from the fact that even if the endorsement game is uncooperative and does not include any reference to explicit coordinated action, the stable coalition obtained at the game's equilibrium is the only one (if the equilibrium is unique) that will probably survive (in the sense that it maintains internal and external stability criteria) in case a (hypothetical) consultation of its members takes place.

Finally, we have showed not only how inherently created value is shared, but also how endogenous coalition formation concepts can become essential to understanding which processes are conducive to this created value. The members of a coalition are not there by chance. They are together in a coalition, because they decided on it after a game took place and following a set of rules that they eventually chose. The regrouping within a coalition is endogenous; it results from their will and from the exercise of their individual rationality. We have mentioned the existence of a vast literature that proposes a multiplicity of other games, different from the one we explored, which is linked to the concept of stability. The literature has reflected the diversity of processes leading to coalitions, especially those in which players can be chosen and, from their point of view, refuse the coalition that does not match their best interests. These contributions constitute an interesting perspective for strategic reflections in terms of analysis, with unparalleled levels of subtlety and remarkable finesse. We invite readers who are a bit more skilled in mathematical formalization and interested in these developments, to peruse the bibliography so as to deepen their knowledge of the subject.

Conclusion

In order to make progress in understanding the relationships between firms and better understand the complexity of the reality faced by managers, strategic management must use concepts borrowed from several scientific disciplines. In this book, we have privileged game theory as one of the axes likely to enrich the approach that predominates in strategic management. The interest of game theory, for the manager, depends on the operative nature of the tools used and their degree of applicability to real and complex situations.

In our view, game theory may be particularly powerful in clarifying the decision-making process and, in a number of cases, it can contribute to decision-making in complex situations where different actors (individuals, firms, governments) interact in an environment characterized by a high degree of strategic interdependence. Exploring a multiplicity of game situations (one-shot games, repeated games in a finite or an infinite context, coalition formation), we have shown how firms can better understand the behavior of their competitors and change their strategy accordingly.

However, for managers, game theory is not a substitute for their own experience in the business world. Their choices are often more "qualitative", more "intuitive". Above all, game theory helps

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managers combine their skills and their ability to perceive the "real" with various more analytical approaches. Quoting the expression from [CHA 02]: "to define and to conduct a strategy, the spirit of geometry and the spirit of finesse must play a duet".

Game theory can help to rationalize decision-making in a context involving two or more protagonists often guided by distinct or even opposing interests. Even in situations where interests may seem irreconcilable and "conflict" seems to be the rule, other possibilities for "cooperation" or coordination may also emerge and, in fact, constitute viable options leading to collectively better solutions. We have seen how the emergence of strategic coordination does not always depend on the establishment of an explicit agreement between the players, but may result from choices made in the context of non-cooperative games. As we have seen in a chapter of this book, these multiple approaches to cooperation (cooperative approach, non-cooperative approach) offer a very rich range of possibilities for the development of managerial strategic thinking.

Paradoxically, while game theory has been applied in many disciplinary fields (Biology, Law, Politics, International Relations, Sociology, Economics), incursions into the field of Strategic Management, one of the areas of the Management Sciences, have been – all in all – rather limited. In recent years, nonetheless, there has been an increase in publications aimed at showing the links between game theory and strategy as it is taught today in university courses. This book has tried to respond to this new enthusiasm by continuing the process initiated in the first book. With the use of case studies representative of current strategic management issues, we have tried to show that game theory concepts can be very useful in providing an original analysis grid for the outcome of several concrete situations, whose lessons can be highly instructive for managers. Through a few examples, we have also shown how economic problems, when treated with a theoretical arsenal that is *a priori* of difficult access to a non-specialist public, can all the same constitute study cases in strategic reasoning for managers as well as for private or public decision makers. In order to do this, it is necessary to transpose both the logical structure and the results in such a way that they fit into the classic strategic management analysis grid. From this point of view, the most recent developments in economic research should be mobilized more often following the spirit of this approach.

Appendices

Appendix 1

The Conceptual Framework of Game Theory and Presentation of Some Simple Games

A1.1. Introduction

In this section, we introduce the main "elements" of a game – which will be developed in depth in the rest of the book. These elements include the definition of a game and its rules, as well as the different strategies that we can attribute to players. Game theory concerns the study of situations in which players (individuals, enterprises, governments, etc.) interact in an environment of strategic interdependence. A game is the physical representation of this situation. We explore some elementary games that will enable us to introduce certain concepts related to the behavior of players (rationality, common knowledge), to their "information set" and the different components of a game, which can be either static or sequential, as presented in other sections of the book. This section particularly introduces one way of describing games: the normal (or strategic) way.

A1.2. What is game theory?

This first section is devoted to the general notions on which game theory is based. In fact, the formalization of any problem related to

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game theory requires the identification of a certain number of parameters. First, it is necessary to define a game and its players, and then we have to determine the number of players, the action variables they have, their knowledge about the other players and about the game itself (that is to say, their information set) and finally, the rules of the game. But before making these notions clear, we provide some answers to the preliminary question: game theory – what is it for?

A1.2.1. *Game theory – what is it for?*

Game theory focuses on the analysis of strategic interdependencies between different actors. It makes it possible to understand how various players interact in a game situation, that is, a meeting place where actions are deployed (the market is a perfect example). Considering that "everyone is not in total control of their fate, we reckon that the participants are in a situation of strategic interaction. The term strategy comes from the ancient Greek, referring to the actions taken by a military leader in the field. The word has kept that sense. However, its acceptance broadened until it covered less bellicose situations, but in which the idea of conflict persists" [THI 00]. In the fields of economics and strategic management, players are interdependent firms (or countries): the behavior of any one of these produces an effect on the others and the best course of action for a firm depends on the strategies adopted by the other firms (see Box A1.1).

Example 1: Two firms must decide whether to produce a top-of-the-line product (TP) or a low-end product (LP). The two firms choose to produce the same product without communicating with each other. To choose its strategy, the first firm must take into account the market share that depends on the decision of the other firm. If the first firm chooses TP and the second company also chooses TP, both will be in the same market and competition will be severe. The market share will be different if the choices are different. The decision is therefore not simple, so we can conclude that the profit of one of the enterprises depends on its own decision regarding the market but also on the decisions made by the other actors.

Example 2: Two firms in the fast food market can choose between three possible locations along a street authorized by the local town council. The locations are left, middle and right. In this example, we can see that the proximity and distance of firms have a consequence on prices as well as on the market share of each firm. Remoteness creates less competition, while if businesses are near, competition is stronger. In practice, there is often a tendency for firms to settle very close to their competitors in order not to let them completely control the market (e.g. Quick and McDonald's are often placed not too far from one another). The two firms simultaneously file their application stating their final choice. But the question is what to choose, which location strategy should be privileged. The answer is not simple because we do not know what the other will choose. It is therefore necessary to go through a conceptual framework to find the solution, which explains the need to resort to game theory.

Box A1.1. *Two illustrations of strategic interdependence or strategic interaction situations*

As a branch of mathematics used, in particular, by economists, game theory is alternately perceived as a language, a technique or an analytical method useful for modeling the behavior of rational players who defend their interests in well-defined situations. It proposes to identify the actors, what cards are in their possession and what their possible tactics are [CHA 02]. It stimulates reflection in situations that can be reduced to simple questions, particularly in the field of strategic management. For example, "should an airline aspire to maximize savings by purchasing all of its aircraft from a powerful supplier such as Boeing, or would it be better to balance its power by turning to Airbus?" [MIN 99].

According to some authors, game theory even considers situations in an evolutive or dynamic[1] context: "the game has a certain length and players take successive positions according to its evolution. From this perspective, there is a natural complementarity between foresight (the study of possible scenarios) and game theory. Similarly, recent literature takes on its full significance when it is coupled with the idea

1 This dynamic dimension of games is sometimes challenged by certain authors (see Chapter 2 on repeated games).

of a game (what makes it possible, for example, to understand the dynamics of an alliance)" [CHA 02].

A1.2.2. *The groundings for a game situation and for different strategies: games and strategies*

In the introduction to his book, [MOU 81] defined a game as "the mathematical object that formalizes a conflict between various agents (the players), that is to say, a situation they judge according to contradictory preferences and in which they can influence certain parameters". The members of an assembly who have to choose one of the assembly to be the president or the executives of several firms competing in a market where they offer simultaneous goods are privileged examples of "players". The attitude of each firm will be determined as a function of the predictions the firm makes about the actions of its rivals. This situation corresponds to a game characteristic as to the interdependence of the interests of the different agents (players), which may lead to situations of rivalry or cooperation. The player must have decision-making autonomy and a purpose, as well as the ability to influence events to some extent [SHU 64].

The purpose of the players is to "maximize" the perceived gain. Each game is associated with rules that, in the case of game theory applied to economy, particularly deal with the chronology of decision-making and the parameters that influence future earnings: cost conditions, quantities, prices and the structure of demand. These rules describe the order of the actions taken by players. Players either make their choices simultaneously (see Chapter 2), they decide sequentially (see Chapter 2) or are confronted with "mixed" situations, typical for the alternation between successive and simultaneous "blows". As we will see later, these different types of strategies can be closely linked to the nature of the information that features in the game in question. All these elements, which are listed in Box A2.2, constitute the basis of a game situation and can be systematically outlined as follows:

– A set of players: governments, individuals. These must be specified and their number determined.

– Rules: simultaneous games or sequential games.

– Strategic “spaces”: Using game theory, we can define, for example, prices, amounts, product features.

– Payoffs: for each outcome, we determine the payoffs and also the market share of each firm.

– Game typology: games are “simultaneous” when players make their decisions simultaneously, without knowledge of the action of others. “Sequential” games are those in which players make their decisions sequentially, after observing a past action (perfect information); also, there are zero-sum and non-zero-sum games.

– Behavior: it can be of the “non-cooperative” or “cooperative” type. In a non-cooperative game, each player takes care of his or her own profit and chooses the decision that maximizes his or her own interest independently. Sometimes it happens that players have to cooperate with others in order to increase their profit. The cooperative framework stipulates the existence of a binding agreement between the players. If the interests intersect, the firm accepts cooperation and signs a binding agreement, otherwise it rejects it.

Box A1.2. *The basics of a game situation*

A1.2.2.1. *Game in strategic form and in extensive form: definition and illustrations*

Games are often described in two opposed[2] forms: the extensive form and the strategic form. The strategic form is also known as “normalized form” or “normal form” (see Box A1.3 and matrix on the next page). During this first stage, we will focus on strategic games.

2 Even a game in strategic (or normal) form can be written out in extensive form by means of information sets. In a reciprocal manner, a game in extensive form can be written out as a normal layout [GUE 93].

N Players = $\{1, \ldots, n\}$
Strategic spaces: $S_1, \ldots, S_n$

$$S = \prod_{i=1}^{n} S_i$$

Game outcome: $s = (s_1, \ldots, s_n)$ where $s = (s_i, s_{-i})$

$$s_{-i} = (s_1, \ldots, s_{i-1}, s_{i+1}, \ldots, s_n)$$

$$s_{-i} \in S_{-i} = S_1 \times S_2 \times \ldots \times S_{i-1} \times S_{i+1} \times \ldots \times S_n$$

Payoffs:

$$u_i : \; S \rightarrow \Re$$

$$u_i(s) = u_i(s_i, s_{-i}), \quad i = 1, \ldots, n.$$

Normal form: $\Gamma = \lfloor N, \; (S_i)_{i=1,\ldots,n}, (u_i(.))_{i=1,\ldots n} \rfloor$

Box A1.3. *Normal form of a game: general case*

In a static game (*one-shot game*), there is no "sequentiality" in decision-making: decisions are either made at the same time by players or they are made at different times without communication among them. In fact, it is not so much the chronological order of decision-making that enables us to place a game in the category of static games (although this may be the case), but the nature of the information a player can handle concerning the strategy of the other player when it comes to making his or her own decision. At the moment of making a decision during a static game, the player is not informed about the opponent's move. All in all, the player makes the decision as if the game was simultaneous even if, in reality, there may be some "sequential" element inherent to the game. For pedagogical reasons, we often resort to simple two-player games, with a limited number of possible decisions.

The set of possible player decisions, denominated *strategic space*, contains all the actions that the player identifies as a part of his or her strategic possibilities. In these simple cases, players (who can act as antagonists or be placed in a situation of interdependence leading to conflictual or cooperative scenarios) do not communicate and seek to maximize their profit at the time that they assume that the opposing party will behave in a *rational* way. Each game is introduced by specifying three elements:

– the type of players (e.g. firms, governments, managers, etc.);

– the strategies or options at their disposal (definition of the strategic space of each player);

– the profit/value that will be awarded to each player when all the players have played a strategy from those at their disposal.

Information is complete when each player knows his or her strategic space, the one of competitors and the payoffs that each player receives for each vector (or combination) of strategies played by the participants.

Such a set is represented by a matrix where all these parameters are specified.

		Player B (PB)		
		Strategy 1 of PB (PB1)	Strategy j (PBj)	Strategy m of PB (PBm)
	Strategy 1 of PA (PA 1)	(., .)		(., .)
Player A (PA)	Strategy 2 of PA (PA 2)	(., .)		(., .)
	Strategy i of PA (PAi)	(., .)	(,)	(., .)
	Strategy n of PA (PAn)	(., .)		(., .)

Vectors (.,.) given in the matrix represent the profits of both players (the first component, the payoff of the first player and the second, the payoff of the second one) when the strategy played by player A is strategy *i* and the strategy played by player B is strategy *j*. Such a combination of strategies, which we write out as vector (strat. *i*, strat. *j*) is called the outcome of the game. As a matter of fact, there are *n.m* possible outcomes for this game. In this matrix, the first player moves vertically (choosing a line in the matrix) and the second one moves horizontally (selecting a column). The payoff matrix provides a complete representation of the game. It describes the game by specifying the number of players, their strategies and the profits obtained from the chosen strategies.

Information is complete when both players know:

– the specified strategies for every line and every column;

– the payoffs attributed to each outcome of the game (the numerical value assigned to every (.,.) vector integrating the matrix).

A1.2.2.2. *Perfect and complete information*

We assume that both players know the potential payoffs before the game begins. Both players are confronted against the same matrix or at least have a similar representation in their minds and are wondering about the best strategy to adopt. According to the rules of a simple game with complete and perfect information, both players must have the same matrix or, at least, a similar representation in mind. Then we say that information is not only complete, but also perfect.

As [SHU 82a] pertinently observed, the term "complete information" (not to be confused with "perfect information") was used in 1944 by Von Neumann and Morgenstern to express a fundamental hypothesis of their theory according to which players, at the beginning of the game, are fully informed about the exact state of affairs and can consequently make all the necessary calculations (see Box A1.4).

On the other hand, the study of "games with incomplete information", which constitute the basis of many practical applications, is fraught with considerable conceptual and technical difficulties and requires the use of probability theory. In these games, the concept of solution is more complex. Take, for example, Bayesian equilibrium, a concept developed by [HAR 67]. The important concept introduced in these games is the notion of uncertainty (exogenous to the model) regarding the effective "type" that is associated with each player. For example, type can be linked to the player's rational behavior (or not). "To have a Bayesian equilibrium, each player must establish a conditional strategy for each of its types, and this strategy must maximize its conditional utility expectancy by considering the (conditional) strategies of other players as data. In other words, if we denominate a type of strategy, a *private strategy,* (known only by the player from whom it is designed, that is why it receives this name), then a Bayesian equilibrium of the game is a set of strategies (one per player), so that the private strategy of each type of player is the best answer for this type, taking into account the strategies adopted by the other players" [GUE 93]. Bayesian equilibrium refers to a situation in which each player chooses the strategy that maximizes his or her payoffs taking into account not only his or her beliefs, but also those of all the other types of players. Incomplete information leads to strategic problems when some players have private information that is not available to the other players concerning the payoffs of strategic combinations.

Definition: complete information

"In the strictest sense, complete information means that all the competitors know, not only all the prices, cost functions and other economic indicators, but also what each other is going to do". In other words, players know all the rules of the game (which must not include any random components), the different possible actions and their possible consequences.

Definition: perfect and imperfect information

"If at every point in the game, each player who has to make a decision is fully aware of what is going on, then this is a perfect game. […] In a game where there is no perfect information, a new element takes on great importance in the search for solutions: the assignment of probabilities to decisions; what, in mathematical terms, comes down to attributing a probability distribution called mixed strategy to the original set of 'pure' strategies. It is perhaps intuitively clear that this is of no use in a game with perfect information like chess, where no player has any secret to conceal (it was Zermelo (1913) who proved this mathematically). However, when choosing colors for chess (one player hides two pawns and the other players has to choose one of his hands), it is obvious that the only way to do this for both players is to assign an equal probability to the right and to the left hand".

Box A1.4. *Complete, perfect and imperfect information: definitions (adapted from [SHU 82a])*

Incomplete information is often associated with so-called asymmetric information. In this book, we will not analyze games with incomplete information, but for illustration purposes only, we will briefly refer to the "classical" situation of information asymmetry concerning the purchase of used cars (lemons), a quite significant example developed by [AKE 70]. The negotiation between a salesperson and a buyer of a used car is complex because of the lack of information about the quality of the vehicle. The salesperson is encouraged to offer a low quality product while the buyer puts forward a low price, insofar as he or she bets that the car's quality is going to be mediocre. In the end, the balance leads to a low price for a product of average quality. However, the two protagonists could have won a transaction at a higher price, corresponding to a product of much better quality. Building on the work of [AKE 70], [DAS 88] proposed a game from the same example featuring a car dealer and a customer. He explained what it is that makes it possible to establish the exchange between players in a context of repeated games (see Chapter 2), all facts that lead to the notion of seller reputation and to customer trust. As [BRO 92] makes it clear:

> "We assume that buyers do not know the quality of a particular car but they do know the average quality of vehicles placed on the market when the (unique) market price is p. At this p price, any salesperson having a car of a p or lower quality offers his car for sale […]. If quality is not observable by buyers, sellers will naturally put up for sale goods of inferior quality than the market price. In this way, even if the agent is indifferent to risk, the plans of buyers and sellers are fundamentally antinomic (because in his frame of mind, the customer has already assumed that he will be purchasing a product of average quality, so he will naturally agree to acquire a good of 'poor quality' without protest). As a consequence, resources should be spent in such a way that it enables agents to get information about the true quality of goods".

A1.2.2.2.1. The payoff matrix

In fact, the matrix is simply the reflection of the preferences of both players regarding all the possible outcomes of the game. It is not so important to reveal the exact amount of the profit that one gets (market share, turnover, etc.) but that each player be able to compare (in terms of expected profit, even if he or she cannot evaluate it very precisely) all the possible outcomes, two by two. Each player must be able to rank the outcomes in ascending (or descending) order, the criterion being his or her own economic interest. If we take as an example of player A, who prefers outcome (.,.) instead of (.,.) , (.,) and (.,.), all the outcomes of the matrix must be explicit on this list. The data collected concerning the preferences of the two players are enough to build an infinity of payoff matrices that respect the preference order. So, we can state that the matrix is a (complete) representation that summarizes all the strategic interdependencies that can take place between the two players: conflicts of interest, convergences, compromise points, etc.

Therefore, the relevant information concerns not so much the figures that appear on the matrix, but the preference order that it is supposed to represent. In order to obtain this preference order, firms must conduct surveys, market studies and prospective analyses. Because information constitutes the nerve of war, it is necessary to have as much precise information as possible in order to classify preferences. Targeting an outcome is making sure that the outcome in question is indeed the one we prefer. An *ex post* classification of preferences will coincide with *ex post* payoffs (*ex post*: when the strategies have already been played out and the market arbitrated) if *ex ante* information about preferences was accurate.

On the one hand, information refers to questions of strategic intelligence[3] and economic intelligence (see Box A1.5), which are crucial in the field of strategic management and, on the other hand, the notions about how information and knowledge articulate with each other now are mostly outdated. In fact, game theory has introduced an additional concept: common knowledge, a notion that we will define later in this chapter.

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3 In game theory, the term “strategic intelligence” possesses a more specific meaning that the one attributed in the field of strategic management because it includes a temporal dimension. Strategic intelligence can be defined as “the behavior devoted to observing the action of others as well as the context, to the point of investing in a costly action, susceptible of increasing flexibility in the future” [UMB 98].

Strategic intelligence is considered as a tool in strategic management [THI 90, MAR 92, KOE 96]. Its objective is to analyze the connections between the organization and the environment in which this thrives. The process involves seeking information and anticipating the needs of the firm, one of whose purposes is, in particular, to increase its market share. For [LES 95], "the purpose of strategic intelligence is to allow the company to reduce uncertainty, in particular by anticipating the breakdowns that may occur in its environment". For AFNOR (Association française de normalisation), it is a continuous and iterative activity, which makes it possible to anticipate or to detect a situation before it has actually occurred.

It is economic intelligence rather than strategic intelligence that is sought by firms. Nevertheless, these monitoring practices, far from helping firms in their decision-making processes, have created even greater confusion because of an exceedingly voluminous amount of information [SMI 87, LES 94], which ultimately led to a lack of attention [SIM 97]. All in all, strategic intelligence can be considered as a subset of economic intelligence. As stated in [BUL 02], "intelligence provides elements of knowledge that can orient decisions"; it is "a device for getting access to knowledge by putting information into perspective".

Box A1.5. *Strategic intelligence and economic intelligence (adapted from [ISC 04])*

Academic works [HAY 86, MAC 84, SIM 82] have insisted on the need to make a distinction between information (which can be assimilated to a flow of messages that exist independently from individuals) and knowledge (which demands a cognitive competence on the part of the individual who has to sort out, process and interpret messages in order to produce new ones. Knowledge is closely linked to learning capabilities and the educational process). This distinction between information and knowledge directly refers to a second problem in connection with the notion of tacit knowledge versus codified knowledge. In fact, knowledge can be partly "codified" (scientific knowledge), and even "objectified". But another part of knowledge may remain tacit. Tacit knowledge points at specific know-how that is inherent to certain individuals or that is integrated in organizations, thus making it difficult to transfer. In this last case, knowledge cannot be described as a "public good".

As we have already mentioned, in game theory we refer to information whose nature (complete, perfect, incomplete and imperfect) conditions the context of the game and influences its resolution. Alongside the concept of information, game theory has introduced the concept of knowledge and, more precisely, the fundamental concept of common knowledge, whose formulation comes from [AUM 76]. This notion refers to the following context: each player can place himself or herself in the role of the modeler and observe, like him or her, the model of which he or she is the actor himself or herself. In addition, he or she knows that other players can adopt the same behavior, each knowing what others also know, and so on. The beliefs of each player on the choices of others are based on the premise that other actors are rational [GUE 04]. As [RUL 98] explains it:

> "The role of common knowledge in a game model is to make the player's introspection fully visible and predictable because these characteristics are key to decision-making. If we put the modeler on stage as an outside observer, like the Nashian regulator, (his own) common knowledge ensures a total transparency of the deliberation process of each player. […] This methodological posture, which depicts an external element to the game, ultimately consists in modeling the decision-maker`s behavior in reference to a norm or a normative system, which appears externally, as regards the concrete actor, as already being there. The question does not concern so much the need for a common set of knowledge that will certainly be challenged but, more logically, the production of this type of knowledge. In this respect, the formation and production of collective knowledge (that is to say, common or simply shared knowledge) respond to a complex problem, conditioned by the operating rules of the social system in which the players are involved".

However, common knowledge raises other questions as well as a number of criticisms (see Box A1.6).

The debates regarding the question of common knowledge often refer to its unrealistic and reductive nature, excluding other important aspects such as experience. “It is generally wrong to consider that individuals can choose their best strategy simply by deduction, without having any previous experience of the situation they are confronting. In certain situations, it is more pertinent to consider that strategic behavior may be the consequence of learning […]. In this context, the elimination of dominant strategies does not result from a reasoning that wonders about the other player’s next move, but from a gaming experience”.

Box A1.6. *The debates around the question of common knowledge (adapted from [CAH 93])*

If we go back to the hypothesis of complete information, this may seem very strong and particularly unrealistic. For example, in the context of two firms responsible for evaluating the payoffs associated with every outcome, it would come down to admitting that two consulting offices made an identical assessment of these payoffs (or preferences) or possibly that the same consulting firm carried out the study for the two firms. However, although the hypothesis of complete information is still relatively strong, in a simple framework, it can enable us to identify the logical mechanisms underlying strategic decision-making. In other words, it is a good structuring exercise for the reflection of a manager, even if the question about the descriptive or normative character of game theory remains open.

In a matrix, the payoff represented therein may not only take on several meanings – depending on the nature of the players – but also be related to different elements:

– a turnover, profit, a market share, a stock market price for firms;

– a level of satisfaction for consumers;

– when the state has to arbitrate, for example, between the interests of several economic agents, payoffs may correspond to a criterion of collective well-being.

An example of a payoff matrix is given in Box A1.7. It is clear that for such a matrix to be built, both firms must be given the means to estimate the payoffs they can achieve when they adopt one of the possible strategies L, M, D. When a firm chooses a strategy, its payoffs depend not only on its own action but also on the action chosen by the competitor. It is up to each company to estimate (for each of its possible actions) the result in terms of profit, market share (or other) and at a more general level, the outcome of the interaction between its action and the one of the competitor. In this sense, the "optimal" strategy sought and whose concept is commonly used is not as simple to define. An optimal strategy changes according to the information that a firm can collect with regard to the intentions of a competitor. For example, if E1 changes its current top-of-the-line strategy and adopts a diversification strategy, it must be able to estimate the payoff it will obtain for each action of E2, bearing in mind, for example, that if E2 remains positioned on L, it will expect to capture new customers with modest incomes without completely losing its customers attracted by luxury.

Let us consider two firms, (F1 and F2) initially specialized in the distribution of a luxury product and who are pondering a redefinition of their market strategy. They have the choice of sticking to this activity (a strategy written out as L, for *luxury*), of reconverting to massive distribution goods at a discount price (strategy M, for *massive distribution*) or of offering both qualities (D for *diversification* strategy).

F2 Firm

		L	M	D
	L	(a_{LL},b_{LL})	(a_{LM},b_{LM})	(a_{HD},b_{HD})
F1 Firm	M	(a_{ML},b_{ML})	(a_{MM},b_{MM})	(a_{MD},b_{MD})
	D	(a_{DL},b_{DL})	(a_{DM},b_{DM})	(a_{DD},b_{DD})

In this way, value a_{ij} represents the payoff expected by F1 when playing strategy i (i possibly being L, M or D) and that of F2 when it plays strategy j (j can be L, M or D as well).

Box A1.7. *Representation of a payoff matrix*

Payoff matrices can represent firms in a wide variety of situations, confronted with different types of decisions: marketing decisions, as we saw in the previous example, but also decisions in the field of human resources.

Let us consider two firms (E1 and E2) that produce a good integrating a technology whose effectiveness depends on the qualifications of employees. The firm can decide whether to train employees or to employ them with their initial level of qualification (low qualification). Training involves increasing the productivity of the training firm, which becomes more competitive than the non-training firm. It can then sell at lower prices (because, to a certain extent, it reflects the cost savings achieved) and it can capture a greater (relative) market share, if compared to the competitor. Training entails a cost that the training firm must face. Then, two scenarios are considered:

– between the two firms, there is no mobility of trained workers; the payoff matrix is simple and the dominant strategy is to train;

– there is mobility of skilled workers, which encourages higher wages in order to attract the most qualified among them. In this scenario, a firm may decide not to train workers itself and to lay off a part or all of the workers trained by the competing firm by means of an attractive salary. We suppose that a firm that does not train its workers may succeed in dismissing a certain number of skilled workers because it has not incurred any training costs, so it may engage in a higher bid so as to attract a few workers trained by the competitor. We assume that when both firms are engaged in a training process, their trade flows (reciprocal mobility) do not drastically alter their gains. The payoffs evaluated by the two firms are summarized in the following matrix:

		Firm 2	
		Training	No training
Firm 1	Training	(6,6)	(1,8)
	No training	(8,1)	(2,2)

When the two companies train their staff, they obtain substantial profits from the fact that they are attracting new customers who did not consume their products before, because of a reduction in prices. However, as soon as one of the firms embarks on a training policy and has a part of its qualified staff dismissed, it will find itself deprived of its customers and will consequently register a significant decline in its profits. It will not have succeeded in capturing the rewards of training so as to sufficiently cover the corresponding costs. In this case, the "dismissing" firm gets an even higher profit compared to the situation in which both firms invest in training costs.

A1.3. Some game examples

Lessons[4] on gaming theory often start with a presentation of the games that enable us to introduce some key concepts specific to game theory and, before moving into further formalization, help us familiarize ourselves with a few elementary notions so as to better grasp some decision-making problems. There are two types of games: "zero-sum" games (two players, one winner and one loser) and a "non-zero-sum" games (the sum of each player's payoffs may vary depending on the nature of the strategies considered). The basic models of zero-sum games are a good introduction to game theory. In this category, there are a large number of board games (pawns, dice, etc.) and "strategic games" (in the military[5] sense), where the payoffs of some agents are obtained at the expense of the losses of others.

4 Numerous teachings about game theory delivered in several universities, both in Europe and in the United States, are available on the Internet and can be explored in the bibliographic references of this appendix. Here, we particularly make reference to the supporting aids of the following courses: *Théorie des jeux: une introduction* by Jacques-François Thisse; *Game Theory & Business Strategy* by Mike Shor (Vanderbilt University); *Competitive & Cooperative Strategies* by Barry Nalebuff (Yale University); *Strategic Game Theory for Managers* by Robert Marks (Australian Graduate School of Management).

5 By the way, these games have made it possible to explain the nuclear military strategy of the United States and the USSR during the Cold War in the 1950s.

A1.3.1. *Introductory games*

A1.3.1.1. *Nim*[6] *games*

These are zero-sum duel games that can be played with balls, tokens, matches, seeds, etc. We have a set of *n* matches. The first player splits this set into two non-empty subsets. The second player chooses one of these two subsets and, at his turn, splits it. If, after one turn, there are still matches in one of the stacks, player 1 and then player 2 replay until there are no more matches in any of the two stacks. No player can jump a turn and the winner is the one who takes the last match.

Stacks A and B / Players	A = 1 B = 1	A = 2 B = 1	A = 2 B = 2
Player 1	He loses	He wins (he can take one match from the stack where there are two)	He loses
Player 2	He wins because he can remove the last match	He loses	He wins

Table A1.1. *Results obtained by players 1 and 2 according to the number of matches available in each stack*

A1.3.1.2. *Hex games*

Invented in 1942 by Piet Hein (Denmark) and by John Nash in 1948, this board game for two players is played on a board in the shape of a diamond with boxes of hexagonal shape (honeycomb platform whose dimensions can vary). At the start of the game, no pawn is on the board. Players place one of their pawns on a box of their choice and the board fills progressively: the first player places black pawns and the second player uses white stones. Each player must succeed in linking the two sides of the board with the color of his or her pieces: the white player wins if he or she succeeds in building a

6 The current name (radical *nim*, which means *to take* in German) was put forward by the mathematician Charles Leonard Bouton in 1901. For a particular presentation of this game, we can refer to [BIN 99].

white line that connects the left to the right side of the board, whereas the black player links the bottom and the top. Once placed, the pawns cannot be removed or changed in their position. The game stops as soon as a player has succeeded in connecting both sides of the board with his color.

Nash and Gale[7] showed that the first player can still win even if his or her winning strategy has not yet been clearly established. This simple game spurred many mathematical reflections: while winning strategies have been identified for small boards, the problem becomes much more difficult for larger boards.

A1.3.1.3. *The "Matching Pennies" game*

It is one of the best known[8] zero-sum games that can be found in many circumstances (football penalty kicks). Its rules are very simple: two players have two coins. Each of these players secretly chooses between "heads" (H) or "tails" (T). Player 1 wins when the strategies played are the same, whereas player 2 wins if the strategies are divergent. The game can be represented in the following matrix:

	Tail	Face
Tail	(1,-1)	(-1,1)
Face	(-1,1)	(1,-1)

A1.3.1.4. *"Rock-paper-scissors" game*

This game is a good introduction to the notion of dominant strategy that we will explore in the next chapters. It can be defined in the following way: one strategy dominates another when it achieves a result that is at least as good as any other strategy, regardless of the behavior of the opposing player. In this case, the dominant strategy is to play "rock", "paper" and "scissors" once over three times. Choosing one of the three options more frequently would be

7 Gale D., "The game of Hex and the Brouwer fixed-point theorem", *American Mathematics Monthly*, vol. 86, pp. 818–827.

8 By the way, this game is interesting insofar as it does not lead to Nash equilibrium when played with pure strategies.

equivalent to informing the opponent of what one intends to play and would allow him or her to win. The payoff matrix associated with the game is such that scissors prevail over paper, which prevails over rock, which itself prevails over scissors (see Table A1.2).

B A	Paper	Rock	Scissors
Paper	0	–1	1
Rock	1	0	–1
Scissors	–1	1	0

Table A1.2. *Payoff matrix obtained by player B*

A1.3.2. *Introductory non-zero-sum games*

A1.3.2.1. *The prisoner's dilemma*

The most common method for highlighting strategic dominance relationships is the "prisoner's dilemma" model, named after A.W. Tucker.

It involves two prisoners, A and B, arrested as a result of a crime committed in common. They are confronted by their judge, who does not have any evidence to prove the guilt of the defendants. As a consequence, the judge offers each prisoner a deal. Players are obliged to make their choice without any possibility of communicating with each other, as they are placed in separate cells:

– if they deny (this presupposes that they have the possibility of communicating with each other and cooperating), they will be sentenced to 1-year imprisonment;

– if they both confess, they will both be sentenced to a 5-year imprisonment;

– if one denies and the other confesses, the first one will be sentenced to a 10-year imprisonment and the second one will be released after 3 months.

		Player B	
		Not to confess (NTC)	Confess (C)
Player A	Not to confess (NTC)	(1 year, 1 year)	(10 years, 3 months)
	Confess (C)	(3 months, 10 years)	(5 years, 5 years)

A1.3.2.2. *The "battle of the sexes"*

The "battle of the sexes" game involves a part of collaboration and a part of conflict. Players want to coordinate their actions, but these are different. In the economic world, we mainly encounter this situation in the field of technological standards: two firms want to coordinate their respective standards, but each firm wants its own technology to prevail (see Box A1.8).

In the example (which gave the name to this type of game), a husband and wife have to decide how to organize their evening. The husband prefers to attend a boxing match, whereas his wife wishes to go to the opera. They want to be together, but they have different tastes. The purchase decision is simultaneous and without mutual consultation.

Example:

		Wife	
		B	O
Husband	B	(4, 2)	(1,1)
	O	(0, 0)	(2, 4)

Possibilities:

– the husband accepts his wife's proposal but is frustrated, unless he negotiates reciprocity for the next time (the lesser bad solution among the bad ones);

– the wife reluctantly accepts her husband's proposal, unless she negotiates reciprocity for a next outing (the lesser bad solution among the bad ones);

– husband and wife agree on a compromise (a different outing), bringing satisfaction and equal interest to each (the worst solution among the good ones);

– husband and wife refuse any compromise, what leads to frustration in both spouses (the worst solution among the bad ones).

Box A1.8. *The battle of the sexes: formulation*

The “battle of the sexes” can apply more specifically to firms (see Box A1.9) and we can find several prominent examples, such as the case of VHS vs. Betamax. A large number of consumer products are complementary to each other, and successfully combine equipment with software (game console and games, DVD player and DVD, etc.). A well-known case illustrates this situation and the “battle of the sexes” game: video recorders and videotapes. Sony introduced its Betamax VCR standard in 1975, which was followed a year later by JVC, who launched its own standard VHS. *A priori*, consumers had no particular interest in choosing one of the two standards. What ultimately counted was that they had to make the same choice. It was a coordination problem. A normalizing organism can play this role and impose a standard. Government aids and the belief in the success of one standard instead of the other can prompt the success of one of the products.

		Firm 2 (F2)		
		H	B	D
	H	(10, 10)	(20, 5)	(12,6)
Firm 1 (F1)	M	(5, 20)	(2, 2)	(4,8)
	B	(6, 12)	(8, 4)	(13, 13)

The prudent strategy for F1 is (H) and the prudent strategy for F2 is (H). (H, H) is the prudent strategy solution.

Box A1.9. *Formulation: application to two firms*

The case of Betamax/VHS [DAI 05, KAY 95, MOR 05] reveals many lessons that go beyond the simple theory of games:

– the failure of a *first mover* strategy: “first mover” advantage, coming here from a technological advance, was not played. Even if the Betamax standard was technically superior to VHS, that was not enough. Technical quality played a very limited role in the choice of consumers. In addition, Sony erroneously believed that its dominance in the professional market of videocassettes would naturally influence the consumer market;

– the VCR industry was a network externality industry in which the value of consumption for a customer of a given product increased in function of the number of consumers: the number of VCR owners conditioned the number of rental stores available for each standard and the choice of consumers would be made according to the greater availability of videocassettes in function of the two formats. Sales of VHS-VCRs exploded in 1983-1988, causing rental companies to offer more and more cassettes available in that format, almost to the point of exclusivity;

– Sony largely underestimated the importance of agreements with film producers who, at the time, preferred to work for the VHS standard. This strategic error, mainly neglecting the "content" factor, was never made again by Sony. In fact, in the 1990s, Sony focused on the video gaming industry and launched a rather quick active policy for establishing partnerships with game publishers, in parallel with the launch and development of its game console: the Playstation 2 (PS2).

The problem of rivalry was also remarkable concerning the format of DVD players, where Sony defended Blu-ray and Toshiba and NEC stood for HD-DVD. This case is the topic for an in-depth analysis in the second part (Chapter 7) of this book.

A1.3.2.3. *The "chicken" game*

Among the games most commonly used, the "chicken" game is another non-zero-sum game. It is known as a coordination game. The game puts in action two motorists who are in front of a crossroads ready to move toward each other. Each player can swerve and avoid disaster (cooperation) or continue on his or her way (defection). The one who falls first is the "chicken". Which will leave the priority? The payoff matrix is shown in Box A1.10.

		Motorist 2 (M2)	
		Straight	Swerve
Motorist 1 (M1)	Straight	(1,1)	(1,2)
	Swerve	(2,1)	(0,0)

Box A1.10. *The "chicken" game*

This game finds many illustrations, especially in international relations (in cases of disputes between two countries, likely to degenerate and reach an armed conflict: they should opt for cooperation but they choose another strategy, leading to an unbridled arms race). The game is also used in other fields. This is particularly the case for the energy sector in the United States, where firms and regulators were involved in such a game in 2001, during the severe crisis that California experienced, repeatedly recording long cuts of electricity [PAL 01], a conflict that acutely reflected the imbalance between supply and demand in this region. At the heart of the conflict was the level of electricity prices (wholesale prices) granted by the major electricity producers. Although the major electricity companies were *vetoing* the construction of new power plants, due to the unfavorable climate for investments in the Californian state, at the same time the Senate threatened to pass a new regulation imposing pricing thresholds. The situation of "relative shortage" maintained by the main producers was similar to the "chicken" game (see Box A1.11). We can also find other illustrations of the "chicken" game in the media sector (see Box A1.12).

> "As the California electricity crisis enters its second summer, the situation seems to be disintegrating into a giant game of chicken. Politicians are trying to pressure producers to cut prices and lower the roughly $5.5 billion tab they claim they're owed from previous power sales. The generators want to avoid being hit with wholesale price caps or dragged into court for price-gouging, a prospect that seems more likely every day. The result is continued uncertainty – and the distinct possibility that many new power plants might not get built. […] Even if power companies are overcharging or otherwise gaming the market to their own benefit, as many have alleged, the state's politicians and regulators have little choice but to work with them to solve the state's power problems. Producers, too, clearly have little long-term interest in exiting what remains of one of the country's largest power markets. This is a game of chicken neither side can win". [PAL 01]

Box A1.11. *The "chicken" game*

As described by Sweeting [SWE 02], the emergence of the DVD in the media sector in the United States was similar to the chicken game. "The development and introduction of the DVD format was a rare case of Hollywood technology in a premeditated effort to alter the economics of the movie system. When the VCH was introduced in the late '70s, it had a radical effect on studio economics, introducing an entirely new revenue stream for movies and cementing the pattern of releasing movies through a series of exclusive windows. […] When TV was introduced, the studios saw the sky falling in on the movie business. That is, until they realized they could make money licensing movies to TV and creating and producing new forms of programming specifically for the small screen – a business that is often more lucrative than making movies. The introduction of DVD followed a very different pattern, however. Early proponents of the new format, particularly Warner Home Video, believed that the studios' video rental business was ultimately threatened by newer digital technology" [SWE 02].

Box A1.12. *The introduction of the DVD*

The last two games we introduced raise coordination problems. The notion of "cheap talk" refers to all communication without costs that takes place before the game really begins makes sense.

> "In the game of orderly coordination, cheap talk immediately allows players to make the desirable outcome the focal point. In the "chicken" game, cheap talk is useless: what is dominant for each player is to verbally announce that he will choose to go straight ahead. However, conflict and coordination are associated in the battle of the sexes […]. Thus, communication may contribute to reduce inefficiency, even if both players are in conflict". [RAS 04]

Appendix 2

Nash Equilibrium

A2.1. Definition and formulation

In games with complete but imperfect information, decisions are made simultaneously and a player has no knowledge of the decision taken by his or her opponent. In these conditions, a solution concept must be found, which consists of determining criteria according to which a choice of strategies is judged to be more reasonable than another [BAR 91]. For this, there are two methods. The first one is to eliminate dominant strategies and favor certain outcomes inspired in principle of individual rationality as a reference point. However, in the measure that the concept of solutions by the elimination of dominant strategies in general leads to too many solutions, "we try to find out if there are any of the possible outcomes that correspond to 'equilibriums', that is to say, which result from individual choices in which no player is encouraged to unilaterally deviate. Each set of strategies having this property (one per player), is called Nash equilibrium" [GUE 93].

Nash[1] [NAS 51] was at the origin of the concept of solution, which enabled the development of many game theory applications and referred to a large number of games with an arbitrary but finite

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1 For further detail about the historical context of the works of John Nash and their repercussions on game theory, the reader may consult the article by [MYE 99]. Nash equilibrium has been the object of numerous commentaries that we find in the writings of [KRE 99].

Game Theory Approach to Managerial Strategies and Value Creation,
First Edition. Abdelhakim Hammoudi and Nabyla Daidj.

number of players, with an arbitrary but finite number of strategies [GON 06]. Nash suggested a stricter criterion for selecting strategies, rather than the simple elimination of dominant strategies. He called "equilibrium" a combination of strategies for which each player's strategy is the *best reply* to the strategies of other players, that is to say, if there is no profitable unilateral deviation.

> "Each player has a set of actions, and the result of the game – in fact, the value of the objective function of each player – depends on the actions chosen by all players. A set of actions (one for each player) constitutes Nash equilibrium if the action of each player is the best for that player, given the actions of the other players". [TIR 83]

In other words, the situation in which each player chooses the best strategy available for him or her, while taking into account the strategies chosen by other players, is called Nash equilibrium. We can show that in the particular case of a zero-sum game, any strategy that is not strictly dominant is a better response to the competitor, which constitutes a peculiarity of this type of game.

To introduce the notion of Nash equilibrium, let us start with the prisoner's dilemma. (C, C) is a solution obtained by eliminating strictly dominant strategies (or by playing strictly dominant strategies). Such an outcome presents the characteristics attributed to Nash equilibrium (C, C). We will later discuss these characteristics in depth.

		Player B	
		Not to confess	Confess
Player A	Not to confess	(1 year, 1 year)	(10 years, 3 months)
	Confess	(3 months, 10 years)	(5 years, 5 years)

Nevertheless, we can note the following. In the case of the prisoner's dilemma, it is preferable for both players to confess and not to accumulate more than 5 years of sentence. But this Nash equilibrium outcome is not collectively satisfactory in the sense that both players could do better if they both were led to cooperate.

So, this game leads to highlighting a game typology whose solution, based on the use of dominant strategies, leads to a collectively disappointing outcome. The prisoner's dilemma reveals the widely held contradiction between individual interest and collective interest. To overcome this deadlock, we can consider that in many cases, this confrontation does not occur only once (*one shot*), but tends to be renewed regularly. Thus, each player gradually acquires information about the other player's behavior (see Chapter 2 on repeated games).

The following definitions illustrate the more general properties of Nash equilibrium outcomes (see the formal definition in Box A2.1 and an equivalent definition based on the best response in Box A2.2).

Property:

We speak of a Nash equilibrium outcome if no player can win by unilaterally deviating from the strategy associated to him or her by this outcome.

Formally, given the following game $\Gamma = [N, (S_i)_{i=1,\ldots,n}, (u_i(.)_{i=1,\ldots,n})]$. The $s^* = (s_1^*, \ldots, s_n^*)$ outcome is a Nash equilibrium if and only if the following property is verified: $\forall i \in N, \forall s_i \in S_i, u_i(s_i^*, s_{-i}^*) \geq u_i(s_i, s_{-i}^*)$

Box A2.1. *Nash equilibrium: property*

For example, we can verify that outcomes (C, C) and (Medium, Medium) confirm this property.

Two players: A and B.

Strategic spaces $S_A = \{a_1, a_2, \ldots, a_n\}$

$S_B = \{b_1, b_2, \ldots, b_n\}$

$MR_A\ (b_j^*)$: it is a strategy played in the space of possible strategies S_A from A, which gives A the best payoff when B has played b_j^*. This definition is valid for $MR_B\ (a_i^*)$.

(a_i^*, b_j^*) is a Nash equilibrium if there is no unilateral deviation from any player with regard to his or her Nash strategy, that is to say:

$MR_A\ (b_j^*) = a_i^*$

$MR_B\ (a_i^*) = b_j^*$

Box A2.2. *Nash equilibrium: property formation*

A2.2. Identification of the equilibrium outcome in a payoff matrix

The question of the existence of Nash equilibrium in a complex game will not be discussed in this book. We are not sure whether there always exists an equilibrium or that it will be the only possible one. So, how can we identify Nash equilibrium if it exists in a matrix?

For each strategy of the "column" player, we determine the strategy that gives the "row" player the maximum gain: we set the first column and we find the row that gives the best payoff to player *i*. The strategy that gives the best payoff with regard to the given column is called "best reaction to column strategy". We repeat the same procedure by setting the second column, then the third and so on. We get all the player's best row answers to the column strategies that this player can choose. We proceed in a similar way for the column player: this time setting a row and looking for the column strategy that is the best answer to the fixed row strategy. We get all the best answers from the column player to the row strategies that this player can decide.

The outcome in which the row and the column are simultaneously identified as "best answers" constitutes Nash equilibrium. Let us apply this procedure to the following matrix game.

		Firm 2		
		G	C	D
Firm 1	H	(4, 2)	(9, 1)	<u>(6, 7)</u>
	M	<u>(5, 4)</u>	(3, 3)	(4, 0)
	B	(1, 3)	(4, 2)	(5, 2)

The underlined payoff vector (in these two components) represents Nash equilibrium: for the H strategy played by F1, the best answer from F2 is D and for D strategy played by F2, the best answer from F1 is H. Now we can associate the notion of Nash equilibrium with certain concepts of solutions we previously defined.

As we will see, Nash equilibrium can be identified by using a process of elimination of strictly dominant strategies but, for this, it is necessary to bear in mind the following properties:

– when the iterative elimination of strictly dominant strategies leads to a unique outcome, this is Nash equilibrium;

– a process of eliminating strictly dominant strategies does not always converge (it can be blocked at an intermediate phase). Therefore, Nash equilibrium is not systematically obtained by such a process.

One can practice showing these properties within the framework of any game matrix.

As for the link between Nash's conservative strategy and Nash's equilibrium, one can verify that a couple of conservative strategies are not necessarily at Nash's game equilibrium: In fact, the outcome in conservative strategies (H, H) does not constitute Nash equilibrium. When playing with cautious behavior, players can arrive at a collectively better solution that is more satisfactory than non-cooperative behavior (Nash equilibrium). But, the achievement of this solution paradoxically demands certain coordination between players, precisely because this couple of strategies is not in equilibrium: if one of the two players knows that the other player will behave in a prudent way, and he or she reacts rationally, he or she will play his or her best response to this strategy. However, we can verify that it may also occur that the couple of prudent strategies in fact constitute Nash equilibrium, as shown by the example in the following matrix:

		Firm 2		
		H	M	B
Firm 1	H	(10, 10)	(20, 5)	(12, 6)
	M	(5, 20)	(2, 2)	(4, 8)
	B	(6, 12)	(8, 2)	(13, 13)

The (H, H) outcome is a conservative solution. It also constitutes the Nash equilibrium of this game.

A2.3. Multiple equilibriums

In many situations, there is not one, but several Nash equilibriums, as in the example of the battle of the sexes shown in Box A2.3:

The battle of the sexes game enables us to show that there may be a multiplicity of equilibriums.

		Wife	
		B	O
	B	(4, 2)	(1,1)
Husband	O	(0, 0)	(2, 4)

The resolution of this game leads to several findings:

– there are here two Nash equilibriums ((B, B) and (O, O));

– the outcome in conservative strategies (B, O) is not a Nash equilibrium. In this case, prudent behavior leads to a collectively unsatisfactory outcome in relation to the two Nash outcomes. The problem is to effectively bring about one of these two outcomes, which requires a minimum of coordination. Without coordination, if both players make concessions and efforts to achieve one of the two Nash outcomes that is favorable to the other, only a collectively catastrophic outcome (O, B) is achieved.

Box A2.3. *Equilibriums in the battle of the sexes*

A2.4. Collective rationality and Pareto optimum

If we take the example of the prisoner's dilemma at the beginning of this appendix, the solution of the game is for both players to confess and not to accumulate more than 5 years. But as we have already pointed out, this solution, which corresponds to Nash equilibrium, does not constitute a Pareto optimum insofar as the two protagonists would achieve a better result if they were both led to cooperate.

		Player B	
		Not to confess (NTC)	Confess (C)
Player A	Not to confess (NTC)	(1 year, 1 year)	(10 years, 3 months)
	Confess (C)	(3 months, 10 years)	(5 years, 5 years)

Provided that the two protagonists can communicate, they seek an agreement starting from (C, C) and reach a unanimously accepted agreement, which is (NTC, NTC), because this deal helps them have their prison sentence sharply reduced. The (C, NTC) outcome is not accepted by at least one prisoner, because player A's payoff increases and the payoff of player B decreases. A similar reasoning can be made for (NTC, C). In the end, (C, NTC) and (NTC, C) are not unanimously accepted. On the other hand, the outcome (not to confess, not to confess) is collectively preferred to (confess, confess) because the utility of U1 (NTC, NTC) > U1 (C, C) and U2 (NTC, NTC) > U2 (C, C)

$$Ui\,(\text{NTC, NTC}) = 1 \quad i = 1{,}10 \qquad Ui\,(\text{C,C}) = 5 \quad i = 1{,}10$$

We say that the (NTC, NTC) Pareto outcome dominates the (C, C) outcome. This is another characteristic of the game: we call it a Pareto optimum.

A2.4.1. *Definitions*

– *A Pareto outcome strictly dominates another outcome* if both players get strictly better profits with the first rather than the second outcome.

– *An outcome is a Pareto optimum* if we cannot find another outcome that simultaneously improves the payoffs of both players. A Pareto optimum does not strictly dominate any outcome.

– *A Pareto dominant outcome* is a Pareto outcome that dominates all the others.

When a Pareto outcome strictly dominates another outcome, players collectively have an interest in adopting the first outcome because of the principle of collective rationality. The problem is that collective rationality can be applied to individual rationality, as in the case of the prisoner's dilemma, but that means that what is collectively desirable may not correspond with what is achieved *in fine*.

Let us observe that a Pareto dominant outcome is necessarily an optimum Pareto. However, a Pareto optimum is not necessarily Pareto dominant, as illustrated in the following example.

		E2		
		A	B	C
	A	(10, 10)	(25,40)	(20,20)
E1	B	(40,25)	(30,30)	(40,25)
	C	(20,20)	(25,40)	(10,10)

The (B, B) Pareto outcome dominates the (C, C) outcome. In this game, there is no dominant Pareto outcome. There may be other Pareto optima such as (A, B) and (C, B). Pareto optima are not comparable in the sense of community rationality. (B, B) is such that there is no individual unilateral deviation because it constitutes Nash equilibrium: (B, B) is the only viable agreement because it can be obtained by simply exercising individual rationality. For both players, strategy B is strictly dominant: the (B, B) solution to the game is a Pareto optimum and, at the same time, a Nash equilibrium.

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