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COMPLEMENTARITIES IN ACTION: MODELING COMPLEMENTARITY THRESHOLDS IN ENACTING A COOPETITION STRATEGY

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Abstract: This paper focuses on the issues of coopetition strategy implementation as well as on the evaluation of the potential limitations of the classical economics of complementarities approach and apparatus as applied to this field and to managerial settings in general. Coopetition strategies' motivations in fact are funded on the concept of complementarity. However, this paper maintains that a closer look at the complementarity issues in coopetition is needed in order to avoid pitfalls in reaping the benefits of coopetition, and at the same time points out that the classical economic definition of complementarity presents shortomings in mirroring real managerial situations. In order to achieve such results, the paper develops a situated model of a coopetition strategy implementation and evaluates the potential unintended effects of this strategy on firm performance, as well as the applicability to a managerial setting of the concept of complementarity as defined in classical terms.

INTRODUCTION

Economics research has rather recently devoted renewed attention to the issue of complementarity, and a new body of literature emerged on the basis of some seminal work from Topkis (1978; 1995; 1998) and Milgrom and Roberts (1990; 1995) which spurred various management research applications too (Porter, Siggelkow 2000), establishing a commonly accepted definition of complementarity in managerial studies. This very notion and definition of complementarity is here being scrutinized in application to managerial issues, as for example it does not encompass the existence of threshold effects in complementary variables and thus advocates for continuous increases of the variables to maximize system output. This paper intends to model the effects of complementarity in a managerial setting, in order to test the applicability of a classical complementarity definition to managerial issues. The model application depicts the effects of a coopetition strategy at single partner level. The very concept of coopetition is founded on the complementarity-based nature of this strategy (Brandenburger, Nalebuff 1996). However, coopetition research has devoted relatively little attention to complementarity issues and their impact on coopetition results. By bridging the coopetition and economics of complementarities research fields, this paper develops a model representing a classical optimization problem in complementarities as applied to coopetition, in order to evaluate potential risks deriving at operational level from implementing a coopetition strategy. The model here developed is a situated one and is based on empirical data from a longitudinal case study of coopetition in the mineral water and soft drinks industry. The managerial situation modelled not only represents a real case example, but also mirrors a managerial situation which is frequently used as an exemplary instance of a complementarity system setting, namely that of manufacturing flexibility vs. product variety decision problems. The results of the study highlight a potential risk of coopetition strategies, namely thresholds effects, as well as the associated risks a wrong understanding of complementarities in a coopetition setting may entail. Results also show how in a classical complementarity setting example thresholds can ensue, contrary to what stated in complementarity literature and as opposed to what entailed in the very definition of complementarity in classical economics. Thus the paper points out the need for both a more careful evaluation of the role of complementarities in a coopetition setting, and the development of a definition and analytical treatment of complementarities that is more geared to the managerial, rather than economics, setting.

Coopetition has been defined as a frame in which firms strive to create value by encompassing both competitive and collaborative instances in a relationship (Brandenburger & Nalebuff 1996a; 1996b). Through coopetition strategies, firms strive to create value by complementing each other's activity at some point of their value chain, while competing at other points (Bagshaw & Bagshaw, 2001; Nalebuff & Brandenburger, 1997; Wilkinson & Young, 2002; Walley, 2007). In their groundwork on coopetition, Brandenburger and Nalebuff define their main conceptual framework, the Value Net, based on the very concept of complementarities (1996a). Complementarities between firms' activities ensue when by doing activities A and B together, the outcome will be higher then if they were performed separately (Siggelkow 2002b). The concepts of interdependence and particularly of complementarity lie at the heart of the concept of coopetition, as firms engage in this strategy with a view to reaping the outcomes of such complementarity between some of their activity realms, by ways of synergies creation and/or value enhancement (Brandeburger & Nalebuff 1997; Lado, Boyd, & Hanlon 1997; Padula & Dagnino 2007; Walley 2007)[1]. Economics research has rather recently devoted renewed attention to the issue of complementarity, and a new body of literature emerged on the basis of some seminal work from Topkis (1978; 1995; 1998) and Milgrom and Roberts (1990; 1995) which spurred various management research applications too (Porter & Siggelkow 2000; Camuffo, Furlan, Romano & Vinelli, forthcoming). In economics, two or more components of a firm's organizational or strategic design are considered to be complements if doing more of one increases the marginal profitability of the other(s). The definition mirrors the concept of complementarity as defined in managerial literature and more particularly as built upon in coopetition literature (Camuffo et al. forthcoming; Bonel & Rocco 2007; Siggelkow 2002; Porter & Siggelkow 2000; Brandenburger & Nalebuff 1996a, 1996b). The economics approach to complementarities helps in modeling how the elements of a firm strategy and structure are linked to one another and, using comparative statics results based on supermodularity mathematics[2], how change in a strategy based on complementarities might affect firm structure and results. (Brynjolfsson, Renshaw, & Van Alstyne 1997; Porter & Siggelkow 2000). As the field of coopetition is called to explore more rigorous, formal research approaches (Padula & Dagnino

[1] For a review on coopetition motives, see Walley 2007.

[2] Please refer to the following section of the paper for a basic treatment of comparative statics and supermodularity as applied to managerial research.

2007; Walley 2007), the apparatus offered by the economics of complementarities provides a conceptually fitting field. Despite the evident bridge between these two areas of research, the economics of complementarities has as yet only marginally entered into coopetition studies (Arora & Gambardella 1990; Bonel & Rocco 2007). I believe applying the concept of complementarities to the field of coopetition might lead to relevant advances in the latter, and yet at the same time contribute to the debate on the applicability and limitations of the economics of complementarities approach as illustrated in the following paper section (Gino & Warglien, 2004; Porter & Siggelkow 2000; Siggelkow 2002b).

In this paper, the research question is based on the issue of complementarity in coopetition, with a twofold objective. First, based on the concept of complementarity as a grounding element in coopetition strategies, a situated, case-based model of coopetition strategy yield at a single partner level is developed. Second, by leveraging on the formal treatment of complementarities recently developed in economics research, the paper also tests, through the situated model, the assumptions underlying this theoretical body of research over a coopetition application. In particular, the model tests the results in terms of economic value creation of a production-based coopetition strategy, and the existence of threshold effects in coopetition. Results import both empirical and theoretical implications. On the managerial side, the situated model suggests that managers should be wary of the shaping of the complementarities embedded in their coopetition strategies, so as not to incur into threshold effects over the complementary variables making up their strategy, that might depress rather than enhance value creation. As for theoretical aspects, this situated model points out some limitations in the assumptions underlying the economics of complementarity approach and suggest that these should be addressed if this approach is to have the applicative power it strives to achieve (Milgrom & Roberts 1995). In this sense, the paper also suggests that coopetition research might both be a well-suited area for theory development in the economics of complementarity field, and a field which would benefit from a more formal approach to research.

In the study, the concept of complementarity is applied to a longitudinal case study in coopetition which is used in order to develop a situated model of coopetition gains and to test threshold effects in coopetition and in complementarities. Previous research shows that threshold effects in the complementary variables making up a coopetition strategy are an important class of unexpected risks of coopetition which might lead to lower firm performance (Bonel & Rocco 2007). This situated model of coopetition yields leverages on case study findings related to a soft drinks and beverages firm engaging a coopetition strategy. As the strategy of the analysed company is mainly production-based (a common setting in coopetition: Annika 2008; Padula & Dagnino 2007), a model of the coopetition strategy as implemented at production level is developed, the results of the strategy in terms of the achievable production economic yield are tested. Thus the case study is used for theory generation and to build a situated model to simulate the potential effects of complementarities in coopetition strategy. As companies engaging in coopetition must decide how much to do so in order to optimize this strategy's value creation potential, the model is geared to simulate the results of such optimization over a production-based coopetition strategy. The optimization simulation shows that the degree of intensity of a coopetition strategy might have an effect on the value created by the strategy itself. The strategy can display threshold levels in the complementary variables it is based upon which if surpassed might lead to suboptimal results and lower, rather than higher, value creation for the firm.

In order to introduce the model and its results, the concept of complementarity is first presented, then discussed with reference to its properties and limitations in application to a (generic) strategic as well as to a coopetitive setting. Having discussed the limitations of a classical, economics approach to complementarities, the paper proceeds to present a situated, case-based model of a production-operations decisional problem stemming from a typical coopetition setting. The model and its preliminary results are then presented and limitations are discussed, along with research next steps. Concluding remarks on the role of formal research approaches and particularly of modeling in the development of coopetition research, as well as on the role of coopetition as a testing arena for the advancement of the field of complementarities economics, close the paper.

COMPLEMENTARITY ELEMENTS

Complementarity among productive factors or inputs can be observed when the level of a given productive factor affects positively the marginal productivity of other productive factors. Concepts of positive interaction such as synergies and value enhancement can be reconducted to the category of complementarity. Literature on complementarities has flourished over the last decade in both economics and management research. In this section a review of the classical concept of complementarities as proposed in the economics research field is presented. The review points out its potential towards a more formal treatment of coopetition issues, to then discuss its limitations when it be applied to more managerial settings. This will in turn allow to explain, contextualize and comment the coopetition model develop in the following section.

The recently developed literature on the economics of complementarities attempts to model interdependencies by relying on peculiar assumptions that employ the mathematics of lattices and its supermodularity properties[3]. In their seminal works on comparative statics, Milgrom and Roberts (1990; 1995) present a theory of complementarities in strategy and organizational design. For example, they describe the relative advantages and complementarities of the mass and lean production systems, formally explaining why mass producers find it so hard to change into lean production ones. Such work relies on supermodularity concepts and posits the importance of considering interactions among activities or productive factors in order to overcome maximization problems in complementarity settings, so as to evaluate the potential for changes on one hand, and the resistance of a system to change, on the other.

Fundamentally, complementarity imports that there is a marked benefit in considering activities within and among firms in terms of their interdependence (complementarity) levels, a result coherent with a definition of the value a coopetition strategy should create as proposed by Brandenburger and Nalebuff (1996). In particular, complementarity studies show that managers not considering complementarities among their decision variables may never find the global optimum set of policies (Milgrom & Roberts, 1995).

The classical economic analysis of complementarities rests on some specific properties of supermodularity: “The implications of supermodularity do not depend on the usual kinds of specialized assumptions […]. For example, we do not need any divisibility or concavity assumptions, so increasing returns are easily encompassed” (Milgrom & Roberts, 1995:184). In other terms, supermodularity is a mathematical property which allows for a very high degree of robustness of the models built on it, a very desirable property for several management research applications. However, the same properties that allow for important contributions to the effect of understanding the outcomes of complementarities in aggregate production systems (mass production versus lean production, for instance) can result as very restrictive towards the analysis

[3] For a thorough review on supermodular complementarity for a management research audience, see Rabah (2005) and Vives (2005).

of other kinds of issues[4]. In order to discuss such limitations and understand how these can help or hinder in a coopetition modelling setting, it is useful to consider the formal definition of a complementarity set under supermodularity conditions.

A set of variables ***X*** ($x \in X \subseteq R_n$) is complementary if a real-valued function $F(x)$ (defined on R_n) has increasing differences in ***X***. That is if the real-valued function is a utility function, can say that the function ($F(x)$) has increasing differences in the components (x_i , x_j, with $i \neq j$), if the marginal utility of the component *i* increases in the presence of an additional amount of component *j* (Milgrom & Roberts, 1990). In other terms, a set of managerial policies (such as flexible production lines and high product variety) are complementary if applying them together creates a higher utility (economic benefit) than if performed alone: investment in flexible production lines is more profitable if the firm uses this higher flexibility to produce a varied range of products; on the contrary the investment was made in vain if the firm only produces does not have a varied range of products but only produces one product version).

In terms of a functional form, if *F(x, y, z)* be a benefit function (i.e. a profit function, or any other benefit one: cost minimizing, etc.) where we let **z** be a vector of variables (namely a set of managerial policies, or firm activities), then in a supermodularity frame the variables ***x*** and **y** are complements if *F(x, y, z)* displays the following properties:

$$F(x'', y'', \mathbf{z}) - f(x', y'', \mathbf{z}) > f(x'', y', \mathbf{z}) - f(x', y', \mathbf{z}) \quad (1a)$$

$$\text{for all } x'' > x', y'' > y' \quad (1b)$$

$$\text{and for all values of } \mathbf{z} \quad (1c)$$

Only if the above conditions hold, not only between *x* and *y* but also for all other pairs of variables (between *x*, *y*, and ***z*** and among the variables constituting the ***z*** vector), does the considered set of variables (*x*, *y*, ***z***) form a system of complements. That is, property (1a) tells us that if complementarity holds, then moving from the lower level *x'* to the higher level *x''* of one variable in the system, will be more beneficial to the system (which will be optimized) when variable *y* is also at the higher level *y''* rather than at the lower level *y'*.

In other terms, property (1a) tells us that if a set of managerial policies or firm activities are complementary, then we will achieve higher results (benefit levels) if when we do more of one policy we contemporaneously do more of the other(s) too: if we were to increase the levels of flexibility of our production lines, we would achieve higher, optimal economics results if we increased product variety correspondingly. Doing more of only one of the activities or policies comprising a set of complementary activities will always lead us to lesser benefit (suboptimal results). In order to achieve optimal results from our activities/policies system, complementary activities/policies should be changed (for example, increased) in groups and not in a piecemeal fashion.

[4] Some important results put forward by Milgrom and Roberts in their formal analysis concern the relationship between complementarity and coordination needs: in the presence of complementarities the maximization of variables in an individual fashion leads to suboptimal results. In fact, many local optima may be present (in the line of landscape theories), but a single profit-maximizing solution exists which requires simultaneous maximization of all the variables. As the search for simultaneous optimization of the variables is carried out, if the owners of this search (eg. different functional managers) each control different variables, then coordination among these potentially diacritic optima might be problematic, requiring movement from one optimum to the other in a coordinated way. Complementarities paradoxically can lead to coordination failure or myopia, and the payoff of the best (and worst) solutions increase (Gino & Warglien 2004).

Properties (1b) and (1c) further specify that for complementarity to be present this "group effect" is necessary but not enough: property (1b) says the group effect should hold true no matter how much we decided to increase, in our example, product variety levels, even to an infinite number of products. Property (1c) states that we are in the presence of complementarity only if the group effect will lead the system to higher results no matter what the rest of the firm policies were like. If production lines flexibility were our variable x and product variety were our variable y, by increasing them together we would achieve a higher benefit regardless of the other practices adopted in the firm (our other z variables): for example regardless of whether the firm required big batches of one product in order to make logistics economically viable. .

Supermodularity formally conveys the notion that the joint application of complementary resources will be more beneficial than their separate use, and as discussed above allows for robust results to be obtained at the economy and industry-wide and full production system levels. However, the very conditions that allow it to do so, can be detrimental when applied to other settings, such as competitive advantage analysis or strategic situations in which complementarities are not isolated in clusters (Gino & Warglien, 2004; Porter & Siggelkow, 2000; Siggelkow, 2002a).

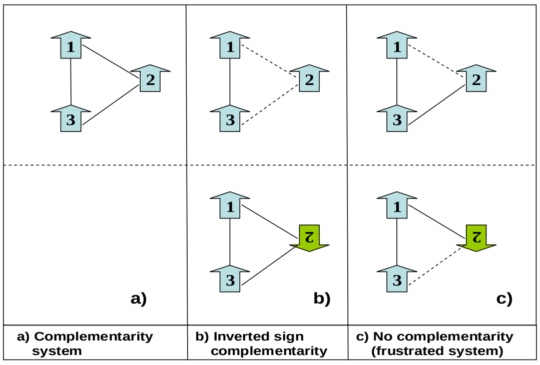
In particular when we apply the above (1a, b, c) conditions to a more micro, firm-level setting we can observe that:

I. condition (1b) requires that the relationship between x and y hold for all levels of ***x*** and ***y***. That means, complementarity should hold as ***x*** and ***y*** are increased or diminished *ad libitum*. However, management interactions may not be constant for all values of the involved activities, but rather only be complementary over a range of their values, but not outside such range (Porter & Siggelkow, 2000). The example modelled in this study represents one such instance.

II. condition (1c) instead requires that this relationship hold for all values of all the other variables ***z***. Which implies that the system of complementarities be free from what Porter and Siggelkow (2000) call "contextuality effects": the same complementarity (and benefit function) should hold in whichever set of variables ***z*** it might be immersed. That is, it should be valid in whatever firm it were applied, and differences in context of application should not impinge on the results. As Porter and Siggelkow (2000) argue, however, condition (1c) does not carry with it results that allow for sustainable competitive advantage, as any organization implementing the same system of complementarities, other strategic or organizational variables notwithstanding, will reap the same benefit value, in contrast with what purported by competitive advantage theories postulating that firm-specific competitive advantage sources be necessary for achieving sustainable advantage (Porter, 1996; Barney, 1991).

III. the three conditions only encompass those cases in which the complementarity cluster (see sub. II) does not show "negative" relationships among the variables (decreasing differences/trade-offs), or when these negative relationships can be turned into positively related ones by inverting the sign of one of the variables (Figure 1). "Supermodular models fail to address the situations in which there is no way to exploit all complementarities without activating conflicting resources or activities" (Gino & Warglien, 2004: 4). An unrealistic setting for the managerial world, for example when considering production activities and product development ones, which typically conflict one with the other. Figure 1 illustrates the differing situations. Figure 1a displays a complementary activity system, indicated by the solid interdependence line. Figure 1b represents a system to which supermodularity can only be applied if the value of decision variable 2 is inverted (the conflicting, negative interaction of 2 with 1 and 3, represented by the dotted line, turns in a positive one –solid line – if the sign of 2 is turned upside-down, and thus the “group effect” is now working). Figure 1c shows instead a system in which the relationships cannot be made into respecting supermodularity conditions (even if the signs be inverted, there still will be conflict in the system). Gino and Warglien (2004) discuss the managerial cases in which this situation might ensue, term this a “frustrated system” and start to explore a model that should accommodate for conflict and yet maintains many of the properties that supermodularity grants and which allow for a model’s robustness and simplicity. The potential of their approach for the coopetition strategy field is here discussed along with further steps of research in the concluding paragraph.

Figure 1: Complementarity systems and frustrated systems (Gino and Warglien 2004: 4).



Given that complementarity managerial issues cannot all be encompassed by the economics of complementarity approach, as shown in the above three points, it appears that there is scope in the field of management for making this field advance. At the same time, the coopetition field itself presents characteristics that call for a more thorough tackling of complementarities in coopetition strategies, since complementarities come to the fore in coopetition as:

- coopetition is engaged into in order to lead two parties to reap higher benefits from their joint activities, than they would be able to do by acting independently;
- coopetition ensues if doing an activity makes the activities of another actor more beneficial or attractive;
- coopetition involves the evaluation of such benefits in a systemic, rather than piecemeal fashion for the partners;
- coopetition stresses the evaluation of interaction in terms of clusters of activities/policies over which it appears more beneficial to cooperate, and others where it is more beneficial to compete, as opposed to supermodularity condition (1c)
- coopetition strategies are delicate and can present threshold effects, as opposed to supermodularity condition (1b).

There seems to be a need to delve under the surface of the complementarity issues of coopetition in order to both better understand and manage them, as well as to verify whether the economic approach to complementarities should not itself be reviewed in order to more correctly treat this kind of strategy and its outcomes. The following section addresses a case study in coopetition in the soft drinks and mineral water industry which is then adopted as a basis for developing a formal model of coopetition implementation. The model will in turn help us test complementarity hypotheses' robustness as applied to a coopetition managerial setting.

TRACKING COMPLEMENTARITIES IN COOPETITION: THE SAN BENEDETTO CASE

Previous literature recognized the risks and investigated failure causes of coopetition. However, literature so far has focused on the fragility of coopetition more at its inter-firm level, rather than at the single partner, intrafirm one. Highlighted risks at inter-firm level include opportunism risks and/or external changes (Afuah, 2000; Bresser, 1987; Faulkner 1994; Gulati, Nohria & Zaheer, 2000; Hamel, Doz, & Prahalad, 1989; Hamel 1991; Harrigan, 1988; Luo, Slotegraaf & Pan, 2006; Yoshino & Rangan, 1995); interest divergences or partner asymmetries, as well as outcome subdivision imbalances (Meyer, 1998; Park & Russo, 1996), and tensions in learning or production dynamics (De Wever, Martens & Vandenbempt, 2004; Dowling, Roering, Carllin & Wisnieski, 1996; Inkpen, 2000; Levy, Loebbecke & Powell, 2003; Luo, 2004).

In his recent review on coopetition, Walley (2007) also observes research has concentrated on the strategic level of coopetition issues rather than at the operational level, which is still under-researched. Existing work on the intra-firm consequences of coopetition has discussed effects on workforce and loss or imitation of critical resources (Bagshaw & Bagshaw, 2001; Bengtsson & Kock, 2003; 2000; 1999; Park & Russo, 1996) or disruption of the business model or of existing practices (Bonel & Rocco, 2007). I believe this stream of research is particularly promising, as it investigates an overlooked class of risks stemming from the operationalization of a coopetition strategy from the point of view of a single partner.

In order to model the effects of coopetition and complementarities at a single partner level, the paper builds its considerations on a longitudinal case study in coopetition which was studied through direct observation over a 5 years span and about which there is availability of production data ranging 10 years. It concerns an Italian soft drinks and beverages producer, San Benedetto SpA, which in the mid nineties started engaging in a range of coopetition relationships with its main competitors: Coca Cola, Pepsi Co, Ferrero, Cadbury Schweppes, Danone. These relationships were based on three main, interconnected elements: co-production; joint new product development; joint new factory development.

The company engaged into coopetition as a strategy to survive in an industry which was undergoing a prolonged maturity phase where consolidation was occurring and where big players were best equipped for delivering on the industry key success factors. In fact the industry main requirements were high levels of economies of scale in production and in turn a continuous drive for market share growth. At the same time, the relatively low margin product pushes companies towards more efficient, low cost operations and production yield continuous incrementation through technical excellence and saturation of production capacity, whereas costly logistics for this bulky yet low margin products call for multiple production locations. On the market side, being always present at point of sale is a must, as thirst is a need that does not wait, even at expense of brand fidelity. Good time-to-market and production response time, as well as flexibility to variable market conditions (seasonality, weather dependency, fashion), are a must. And yet, the market is mature and overcrowded, and distribution channels increasingly concentrated. This means that high levels of investment in innovation are required to attract customers, and at the same time convince distributors to provide access to their overcrowded shelves. Brand and bargaining power become essential in order to gain access to distribution: in the eyes of distributors, beverages are bulky and display a low margin/linear meter ratio, which means that to get to the shelves a well-known brand name and/or very competitive price are needed, as well as production flexibility and time response for improved levels of service. These factors explain why small players are gradually giving way to bigger ones, who can better exploit economies of scale and enjoy a stronger market position concerning access to multiple distribution channels, thus being able to achieve a lower cost structure allowing for more intensive investment in terms of innovation, R&D and brand building.

In this setting, which started emerging about ten years ago, San Benedetto was positioned as a middle-sized player with specific capabilities in product engineering and line production efficiency. Thanks to a history of insourcing and the collaboration with a sister company (Sipa S.p.A.) specialized in designing and producing bottling lines, San Benedetto enjoyed very high levels of production efficiency and new product engineering. It was the first company in Europe to start producing PET bottles, a move away from costly glass bottles, as well as PET bottling lines. It was among the first to develop a production system based on aseptic bottling processes, leading to lower production time and cost, and increased shelf life and product quality. The workforce had a very low turnover and was trained to shop-floor innovation in production processes and machinery. This also meant the company had a very integrated system for new product development which leveraged on very close relationships between the marketing and production personnel, leading to very low product development time and industrialization costs. These competitive advantages in one of the most buoyant consumer markets for mineral waters and beverages in Europe, Italy, attracted the attention of some of San Benedetto's major competitors, and as the company was looking for ways to grow and emerge on the consolidating market, coopetition based on coproduction and joint product development first, and on joint factory development in a subsequent moment, appeared as the most viable strategy for the firm. Today the company's market share ranks respectively in the first and second position with regard to mineral waters and soft drinks in Italy.

Initially, San Benedetto started co-producing bottled drinks for its coopetitors. In 1984 the firm signed a franchising agreement with British Cadbury Schweppes International to produce and distribute its products in Italy. The second important agreement came in 1988 with Pepsi Co. International to produce Pepsi and Seven Up, both plastic bottles and cans. In the same years, the firm entered into foreign markets through dealers, wholesalers, and traders of the final markets (e.g., in France, ex-Yugoslavia, Denmark, South America, Hong Kong). In the nineties the company signed other important coopetition agreements related to the commercialization of a break-through technology for bottling operations, namely the aseptic bottling line technology. Until that time, soft drinks needed high temperature sterilization in order to become aseptic and ensure a long enough shelf life for commercialization purposes. Once again, San Benedetto foreran the industry's trends and aimed at developing a leadership in this technology by internal development. The firm studied, adopted and continuously improved this innovation, in spite of its high costs, just as it had done with the PET technology. The innovation brought in a cascade of correlated innovations and expanded the firm's portfolio of soft drinks (juice-based, milk-based, vitamin-added, and so on). In less than ten years, the firm became a manufacturer of aseptic bottling lines not only for internal use, but also for its main coopetitors. In fact, San Benedetto leveraged its technical abilities by initiating a new business in selling production lines to third parties and competitors, or injecting them as capital in technology transfer based joint ventures outside the national market, thus also gaining new market openings for its own production.

Newborn joint ventures aided the firm's growth through revenues by both the selling of lines, and the appropriation of a percentage on the margins from the joint venture partners' sell out. This helped San Benedetto in cashing-out from the continuous investment it had always made according to its insourcing and do-it-yourself practices, thus avoiding it to become too rigid as a result of internal investment costs. Last but not least, collaboration with global competitors allowed the company to gain access to strategic know how in fields such as market-driven new product development, quality control and logistics. San Benedetto's do-it-yourself policy along with continuous knowledge transfer from its coopetitors explain the firm's leadership in national and international markets. The company's coopetition strategy was in fact devised to achieve a set of direct goals which were measured in terms of increased revenues and production profitability, especially through improved production capacity saturation and increased production unit marginality, as coopetitors' products were being mounted on the production lines at a higher per unit margin. The company also enjoyed other indirect benefits (quality standards know how acquisition, market segmentation and related market-driven product innovation development), although these were never quantified internally and only informally entered the decision processes in the initiation and management of the coopetition relationships. Table 1 illustrates the main kinds of coopetition agreements the company entered into, main coopetitors and the benefits the company derived as related to the industry requirements.

Table 1: Coopetition strategies at San Benedetto: a typology.

TYPE OF COOPETITIVE RELATIOHSHIP AND PARTNERS	TERMS OF THE COOPETITIVE RELATIONSHIP	COOPETITION-DRIVEN BENEFITS
Coproduction (with Coca Cola and Nestlé, PepsiCo International, Cadbury Schweppes, Danone, Ferrero, Coop, Carrefour)	Yearly contracts define content and rules of coproduction (volumes ranges, prices, timings, breach and delay penalties, including payoff and penalties in case of production delays or cancelled orders). All contracts have been constantly renewed over the years and have become less strictly specified over time. Full product specification is provided by the partner. Raw materials provided by the partner.	Production economic yield incrementation through higher marginality mix and higher volumes.
Joint new product development (with Cadbury Schweppes, PepsiCo International, Ferrero, Danone)	Co-development and co-design of new products (content and/or bottle). San Benedetto then carries out all the production of new products jointly developed. Collaboration can also imply co-investment for new technologies development and new manufacturing lines building.	Production economic yield incrementation through higher marginality mix and higher volumes. Through long-term relationships with top-level industry players, know how acquisition and development regarding quality control, market-driven new product development, marketing
New factory joint development abroad (with Cadbury Schweppes in France, with Danone in Poland, France and Spain, with Coca Cola and Nestlé in Germany)	San Benedetto entered into non equity alliances and in joint ventures abroad. It sold or bestowed bottling lines and provided ongoing technical expertise for their set up and maintenance. San Benedetto also manages all production processes. Partners typically manage all the	Revenues by appropriation of a percentage on the margins from the alliance's sell out. Same economic profile revenue stream structure as in coproduction, based on production economic yield measures. Access to new geographical markets and investment and risk

	other processes in the new factory, including products' commercialization.	sharing. If bottling lines not bestowed: revenues from sale and maintenance of bottling lines to the new factory

In San Benedetto coopetition-related activities, such as coproduction both in the main Italian factory and abroad and joint new product development (see table 1), did leverage positive complementarities between coopetitors' practices. However, as emerged in this case study research (Bonel & Rocco 2007), positive complementarities appeared to reach thresholds. This happened for example when coproduction implied a boost of set up times due to the large increment of external products produced internally as compared to the pre-coopetitive status quo. In the case study it was observed that managers tried to satisfy equally internal and external production requests. To San Benedetto's managers, coopetition implied producing internal and external products according to a fifty-fifty logic so as to increase profitability. However, the very coopetition-related complementarities managers were trying to leverage on in order to achieve better performance show threshold effects which depressed line profitability. The case is a particularly interesting one for analyzing the effects on profitability of the implementation of a coopetition strategy at production level, as it displays several long-term coopetition relationships and a clear coopetition strategy clearly focused on a narrow realm, production, which not only reduces model variables but has also been widely studied in optimization research. A situated mathematical model is adopted to explore the existence of optimal paths and optimization rules for a savvy implementation of coopetition so as to avoid thresholds effects. The example used for discussion, model building and model testing is based on San Benedetto's production system and data. The company's operations are a typical production system furnished with flexible automation machines. Based on this characteristic, the firm would find increasing product variety a source of complementarity-related profitability increase which it pursued through coopetition. Flexible manufacturing systems and product variety are in fact complementary elements reinforcing each other: the wider the product variety, the more valuable are the investments in increasing the flexibility of the manufacturing system; conversely the more flexible the manufacturing system, the greater the benefit, and the lower the cost, of increasing product variety (Milgrom & Roberts, 1990). Considering this, and as an explicit assumption founding its coopetition strategy, the company needed to increase product variety as to matching flexibility. As the possibility emerged of starting to produce for its competitors, the company envisaged multiple benefits arising from a coopetition strategy of co-makership: besides making flexible manufacturing investments more remunerating, coopetition would saturate lines in a seasonal business and grant for greater stability in orders in a weather-prone business; it would increase overall marginality through an asymmetric margin mix structure *vis a vis* coopetitors.

However, the benefits San Benedetto looked for in its coopetition strategy also encompassed some costs. In Milgrom and Roberts' terms (1990; 1995), the question was: did the coopetion strategy complementarity hold for all values of manufacturing systems flexibility and product variety as implicit in condition (1b) above, or could limits in the levels of these two variables be envisaged which, if breached, might lead the firm to lower, suboptimal yield results? In the next paragraph a situated model of this situation is proposed.

COOPETITION AS A TESTING GROUND FOR SUPERMODULAR COMPLEMENTARITIES RESULTS IN A MANAGERIAL SETTING

A situated model specification for complementarity testing over empirical data

In order to test for the robustness of the described classical comparative statics results put forward in complementarity economics, which maintain that complementarity holds for all levels of the complementary variables, a model was developed that simulates a typical complementarity situation as described in seminal works on comparative statics (Milgrom & Roberts, 1990; Porter & Siggelkow, 2000; Siggelkow, 2002a; 2002b), but at the same time is set into a coopetition setting. The model is a conceptual testing one, and it is also situated in that it was developed on the basis of the above-described San Benedetto case study of coopetition in the soft drinks industry. The model being situated, it was possible to test its validity and robustness, allowing for greater analytical streamlining without missing out on empirical soundness: through an iterative process, the firm's coopetitive production setting was identified by collecting primary and secondary qualitative and quantitative evidence. The model structure and hypothesis were set up, and iteratively tested with the subjects involved in the analysis both at managerial and shop-floor level, so as to increase the external validity of the analytical construct and specification (Yin 1989). The data concerning the case were collected over a five years span through field research based on interviews at managerial and shop floor level, primary and secondary data analysis including production line data, and observing participation including researchers' work on the firm's production lines with a production co-worker status. The goal of this process was to reach the greatest analytical simplicity, without losing empirical feasibility. At the same time, the model adopts a classical structure in production yield optimization processes, and is thus in its most basic structure a generic model.

The model describes a decision making problem in a given coopetition setting concerning the production system of San Benedetto. In the model, the firm runs a manufacturing line with given levels of production flexibility characteristics, has already engaged in a coopetition strategy, and must now decide how to optimally allocate its weekly production time on this line to San Benedetto products (internal products), and/or to the products of its coopetitors (external products). In the model, the decision to enter into a coopetition strategy is taken ex-ante with respect to production decisions, and is therefore exogenous to the model itself. The decision making modeled then concerns the evaluation of the benefits in terms of economic productivity optimization of increasing or decreasing the amount of production of internal (San Benedetto) versus external (coopetitors) products. The model allows us to simulate the effect of implementing a production-based coopetition strategy on value creation at production level. It shows whether as postulated by both complementarity and coopetition current literature this value will increase constantly no matter how much the coopetition strategy intensity is increased, or in other terms, regardless of the relative weight of coopetitors' versus internal products mounted on the line. The hypothesis is that this is not the case. In particular, the hypothesis to be tested through the model is:

> *(Hipothesis 1): contrary to comparative statics results from the economics of complementarity, the output (yield) of a complementarity system, which is here situated in a production coopetitive setting, will not increase in the values of the complementary variables x and y for all values of x and y, but will display a threshold level in the variables, after which yield starts declining.*

Any production system (or a manufacturing line) can be evaluated in terms of productivity, which can be calculated in pieces per production time unit, or in terms of economic yield, if productivity be assessed on the basis of the profit contribution of the considered production system. Such productivity can be calculated, and this model does so in terms of economic yield. Any manufacturing line or plant displays a technical productivity level which corresponds to its maximum output performance possible in technical terms. It also displays an empirical productivity level, which is a function of the actual utilization and scheduling of the line. Typically, empirical productivity does not coincide with technical productivity, but rests at lower levels. For example, a production line, however flexible, requires set-up times when a new kind of product is mounted on the line with respect to the previous production batch. In a bottling line, for instance, set up times depend on the washing of the pipes, the lowering or raising of the liquid spouts and fine-tuning of the mechanical specifications, and on sanitization runs. The loss of production time due to set ups engenders costs, then, which tend to curtail the technical productivity of the line. On the other hand, a line can see its productivity increase if the value of the products it runs is higher (in terms of marginality, or of value for the customer –as happens in portfolio completeness issues – or simply of quantity), in a specular way with respect to set up times. For this reason, firms invest in manufacturing lines that allow for greater flexibility, and in reaping this flexibility potential by increasing the range of products run on the line they strive to maximize line economic productivity.

Based on the above considerations, let us describe the monetary output of a bottling system as follows[5]:

$$(1) \qquad \underbrace{(600-\alpha(x-1+y))(1-\delta)(1+\frac{x-1}{50})}_{\textbf{Internal profitability}} + \underbrace{(600-\alpha(x-1+y))\delta(1+\frac{1.2y}{50})}_{\textbf{Coopetition-related profitability}}$$

x	Number of internal products run on the manufacturing line
y	Number of external (coopetitors) products run on the manufacturing line
600	Total technically maximum monthly hours of production
α	Set up time coefficient per product change
$600-\alpha(x-1+y)$	Actual hours of production net of set up times
δ [r< δ; δ<s; r>0; s<1]	Proportion of production time allocated to external products
$1-\delta$	Proportion of production time allocated to internal products
$1+\frac{x-1}{50}$	Unitary margin of internal products
$1+\frac{1.2y}{50}$	Unitary margin of external (coopetitors') products

[5] For model explanation purposes, we keep specification of the model at fictitious values for simplicity.

The function (1) describes the economic yield achieved by a manufacturing line, where *x* is the number of internal products that can be run on the line, and *y* the number of products from coopetitors. The two summands describe the revenues coming from the production of internal and coopetitor's products, respectively. By this clear bi-partition of the summands, the model highlights the overall value contribution the implementation of the coopetition strategy brings to the profitability levels of the line. Optimization analyses are developed for both a specification of the model based on empirical parameters drawn from San Benedetto production data (Figure 2) and one based on a situated specification that is still coherent with reality, but not fully empirically determined and as such displaying more generalizable results.

Based on empirical data from the case study, it is here assumed the system can run for a maximum of 150 hours per week (600 hours a month), and in each hour it can produce a batch of bottles, allocating a proportion $(1-\delta)$ of total production time to internal (in our example, San Benedetto's) products, and a δ proportion of production time to external products (coopetitors' products). This production quantity is then multiplied by the marginality contributed by producing an internal, rather than an external product[6]. Marginality levels 20% higher for coopetitors' products as compared to internal products marginality also reflect case evidence. The model specification here presented is referred to actual company monthly production data. It reports the data from a specific production line, line 65, which is used for production of internal and external products. Production data used refer to 2007. In particular, the parameters of function (1) have been empirically specified as from Table 2 and as resulting from company data for production line 65:

The level of δ reflects a corporate decision regarding how intensively the firm is pursuing a coopetition strategy, by committing with coopetitors to given levels of production of external products in the annual contracts and as spelled out in corporate-issued lump-sum production budget schedules. At the implementational, production level, the managerial question is: how should San Benedetto detail production scheduling and commercial policies? Could the firm increase its production economic yield by increasing the variety (variable y) of external products run on the lines? And if yes, to what extent? Complementarity economics answer to this question by saying that if the production line is flexible, as line 65 is, then increasing yield levels can be reaped by increasing product variety run on the line. However, as will be shown as product variety is increased, a threshold is reached and a certain pattern of yield maximization emerges that is deviating from the managerial euristics applied by the firm and as proposed by complementarity studies.

It is worth noting that although the model is a situated one (some parameter specifications are case-based), it is in fact structured coherently with general optimization models in production, and as such has a more general validity beyond its current case-based specification. In fact production economic yield optimization functions typically encompass a measure of the role of production complexity in order to account for its positive and/or negative impact on production profitability. This is generally expressed in terms of set up times as a measure of role of production planning complexity in depressing profitability, and of marginality mix as a way of expressing positive the role of production planning complexity (or richness, in a positive connotation) in enhancing profitability (Chase, Jacobs & Aquilano 2006). In the model, the driver

[6] The marginality terms of the function reflect the fact that increasing product variety (increasing x or y) leads to higher marginality thanks to product mix effects. Besides, the marginality term in the second part of the function shows that the company typically achieves an extra 20% unitary margin on products produced for its coopetitors with respect to internal products.

for complexity is the intensity of coopetition (number of coopetitors' products mounted on the line) and set up times depressing line profitability are coopetition-driven, as is marginality mix level which in turn contributes to enhancing line profitability. Still regarding the model structure, it should also be pointed out that whether the firm employs single-product lines or flexible (multi-product) ones is a decision the firm would have to make independently from having to decide about the mix of internal/coopetitors' products it wants to produce[7].

Table 2: Empirical specification of the parameters for the model represented in equation (1)

600 hours	Production line 65 maximum monthly technical productivity
70%	Actual monthly productivity of production line 65
1.99	α with: α =(600*0.3)/93=1.99[8], where 93 is the actual number of product batch changes carried out on line 65 in the given period
15	*x* = number of internal products run on line 65 in the given period
78	*y* = number of external products run on line 65 in the given period
17%	*δ* = production time actually set by corporate level as allocated to external products production
63%	1-*δ* = production time actually set by corporate level as allocated to internal products production
+20%	Higher marginality deriving from producing external as opposed to internal products

Finally, note once again that in this model the decision of coopeting is *ex-ante* with respect to the model itself. In fact, it is assumed that *δ* reflects an *a priori* decision taken by the corporate level with the coopetitor when signing a new yearly contract. The production scheduling must accommodate demand by coopetitors when it increases, but maximum timing allocated to such production is preset at *δ* level. In the real world, coopetitor's demand fluctuates during the year depending on the weather. Here, model specification is as related to peak season, in the summer. By exogenously varying the level of *δ*, the analyst can conduct a sensitivity analysis on the level of coopetition the firm has strategically committed to, and on the basis of which it now would like to optimize the production system under complementarity. For example, if *δ* were set at 0.5, then the firm would be equally allocating its production time to internal products and to

[7] In the model, the number of internal products run on the manufacturing line, represented by variable x, also is a proxy for the level of production flexibility of the line itself, as it is reasonable that a firm engaging in coopetition will do so, based on a set ability to produce more than one product on a manufacturing line. Therefore, as x grows we go from one product production line to multi-product production line. We assume the line allows for all the flexibility necessary for accommodating more than one internal and more than one external products.

[8] α represents the set up time coefficient attached to a product batch change on the line. It can be estimated by taking the actual waste of productivity time of the line (technical productivity*(1-actual productivity%)) and dividing it by the number of product batch changes scheduled and carried out on the line in the given period (93). Therefore: α = (600*0,3)/93 = 1,99.

coopetitors products. If δ were set at 0.75, the coopetition strategy would be more intense, as only 25% (= 1-δ) of its production time would be allocated to internal products. In our example, once a given intensity of coopetition has been decided upon, the company has to decide how to ride the complementarities liberated by that very level of coopetition intensity: should it strive to optimize line yield by incrementing external product variety, and up to what level? The dependent variable in the function displays in fact the monetary yield the system will have across varying levels of commitment with coopetitors in order to ride the "product variety/manufacturing flexibility" complementarity over a coopetition strategy.

The model specification thus rests on the following assumptions:

1. Coopetition strategy decisions are exogenous: a coopetition decision must have been taken before the model needs to be applied. In fact, potential coopetition problem issues such as threshold effects will only appear if a coopetition strategy is in place.
2. δ levels, displaying the proportion of production time allocated to external (coopetitor) production are exogenous to the model. An alternative, endogenous δ model specification encompassing δ as a function of x and y, was also developed but does not lead to significant differences in model results in the domain of parameters of this paper. For simplicity and in order to streamline the model, in this paper an assumption on δ exogeneity has therefore been made.
3. Set up times are linear in the number of total products (x+y) and are not peculiar to x or y, as is typical when running product batch changes across one same manufacturing line.
4. Marginality is linear in the number of products. That is, in this model product mix and product range completeness effects are not encompassed[9].
5. Unitary margin achieved through production of products for coopetitors is higher than marginality achieved producing internal products. For this situated model, San Benedetto's managers estimate a 20% higher unitary margin.

From both the case-based validation procedure and the further experimentation on alternative, more sophisticated models, this specification set and its underlying assumptions appear to be synthetic, feasible and robust over the specific situation the model is geared to represent.

Complementarities' threshold effects in coopetition

The model specification above described can be used in order to simulate production yield maximization for a firm which engaged in coopetition. With this respect, two sets of questions arise for managers in this situation and which the model addresses:

I. If a firm were to maximize its production economic yield, would striving to achieve ever-increasing levels of product variety lead the company to an optimum, as classic complementarity analysis maintains (Milgrom & Roberts, 1990; 1995)? Or do threshold effects emerge?

II. How should the increased levels of product variety be achieved? In other terms, should the firm strive to maintain a balance between the level of variety of internal products, and the level of variety of products for coopetitors, as in fact San Benedetto's managers

[9] A model specification encompassing such product mix effects on marginality has been developed and does not have significant effects on the results. This model variation specification and results are available upon request to the authors.

tended to do? Or should a different coopetition implementational path be chosen if coopetition results were to be optimized?

Result 1: There exist threshold effects in coopetition which if ignored can lead a partner to suboptimal decision making on complementarity issues when implementing the strategy

Figure 2. Complementarity thresholds in a production-based coopetition strategy. Results from empirically spefied parameters as of Table 2.

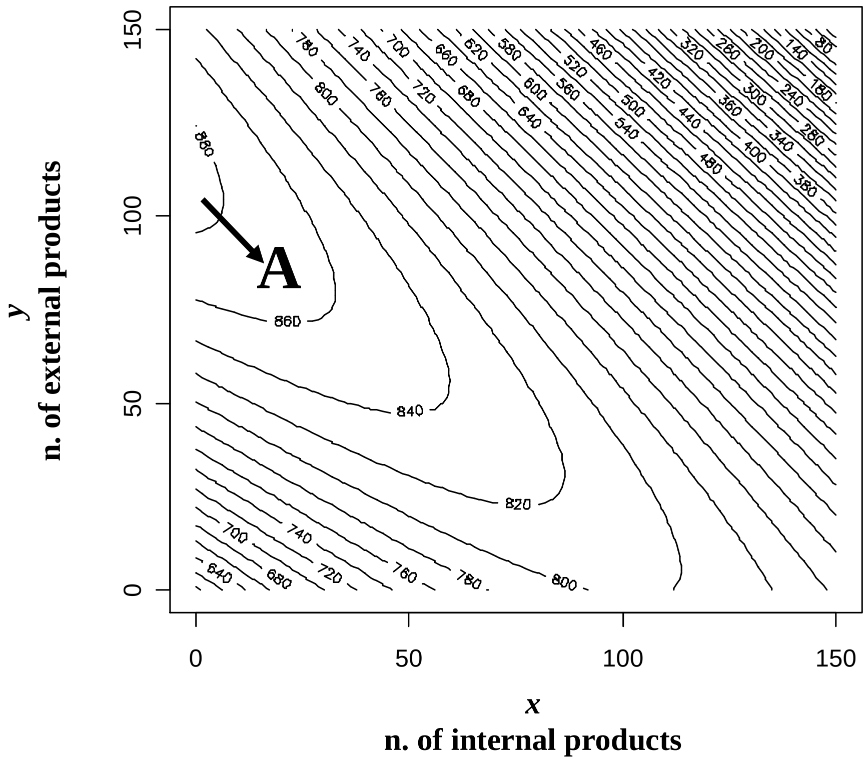


Figure 2 shows the monetary output by representing the contour lines corresponding to function (1) for δ = 0,17 and α = 1,99. The complementarity example here illustrated does in fact present threshold effects: implementing a coopetition strategy at production level leads to superior results, but the result is not holding for any choice of *x* and *y*. As the graph shows, the yield levels represented by the contour lines initially increases (from 640 to 680 and so on) with the levels of *x* and *y*, as expected in a complementarity setting: doing more of *x* and *y* simultaneously does initially increase economic productivity. However, a closer look at the graph will show that complementarity will not hold true for all values of *x* and *y*, thus breaching supermodularity assumptions which are based on this very condition being verified (see condition (1b) in the second section of this study). After a yield growth region, in fact, a complementarity threshold effect will ensue, leading to decreasing yields.

Thus, *(Hypothesis 1)* appears to be satisfied: complementarity in a coopetitive production setting does not behave according to supermodularity. If a firm in this situation were to follow the indications given by complementarity economics, it would indeed incur in initial yield increases, but as product variety increased, the system would achieve a threshold level and the firm would then start seeing its yield decrease. That is if the firm, given its choices concerning the levels of manufacturing flexibility it wishes to adopt, were to increase the number of external products (products for coopetitors) incorporated into production scheduling, it would initially experience a yield brought about by a marginality increase high enough to offset increasing set-up times; but after a certain level the latter will start to dominate, leading to an excessive fragmentation of batches and determining soaring set up costs and a decrease in line yield. Similarly, moving towards increasing levels of internal product variety will also increase costs leading to the same result, although even sooner —at an even faster pace, given the lower profitability of internal products.

This analysis leads to another important result regarding the coherence between decisions at the strategic and functional-operational levels. During the empirical observations, when operational managers faced production capacity allocation problems, they tried to balance internal and external products apart from the coopetition strategy taken at the corporate level. In other words, they tried to commercially push and produce an equal part of internal and external products to satisfy both internal (San Benedetto) and external clients. The formal analysis demonstrates that striving to maintain a balanced portfolio might please clients and coopetitors, but does not necessarily represent the optimal solution in monetary terms. In Figure 2, a mix of $x = 10$ and $y = 109$ represents the optimal solution. With the current production capacity and the superior marginality currently enjoyed by external products in San Benedetto, the firm would optimize yield by strongly focusing on the production of external products, other considerations standing.

In general:

Result 2: A decision taken at strategic level to engage into coopetition should be then rolled out coherently at functional and operational level, lest suboptimal decision making occurs which might lead the firm to experience suboptimal yield levels.

A coopeting firm facing a production capacity allocation problem such as the one here described might consider producing levels of internal and external products that are balanced, for example moving along the bisector line in the graph in Figure 3, which depicts the general model of equation (1) with a general model specification (parameters are not empirically specified but only situated) with $\delta = 0{,}5$ and $\alpha = 1$ in which managers at corporate level follow a balanced path to coopetition strategy. The firm in this setting would thus be increasing product variety of its own product portfolio together with the coopetitors' portfolios that are manufactured on the company's lines. The firm might find this to be a sound, well balanced solution, and it would experience increasing returns in implementing this decision (until it reaches the x and y threshold level) which would appear to confirm this decision. Although the company might appear to be on an optimization path (for example, the bisector line in Figure 3), such path is a suboptimal one and will only lead the company to a local optimum. In fact, if the company were to move away from the bisector, and thus abandon a balancing strategy in product variety decisions, it might achieve a higher level of yield. This higher level is achieved in point A, along a product variety growth path markedly favouring a higher number of external products over a higher number of internal ones. In other words, in our example the company might achieve higher yield results if it decidedly moved away from a balanced internal/external product variety growth path, and instead pursued a growth that fitted with the strategic decision of engaging into coopetition.

Figure 3. Complementarity thresholds in a generic coopetition situated model example.

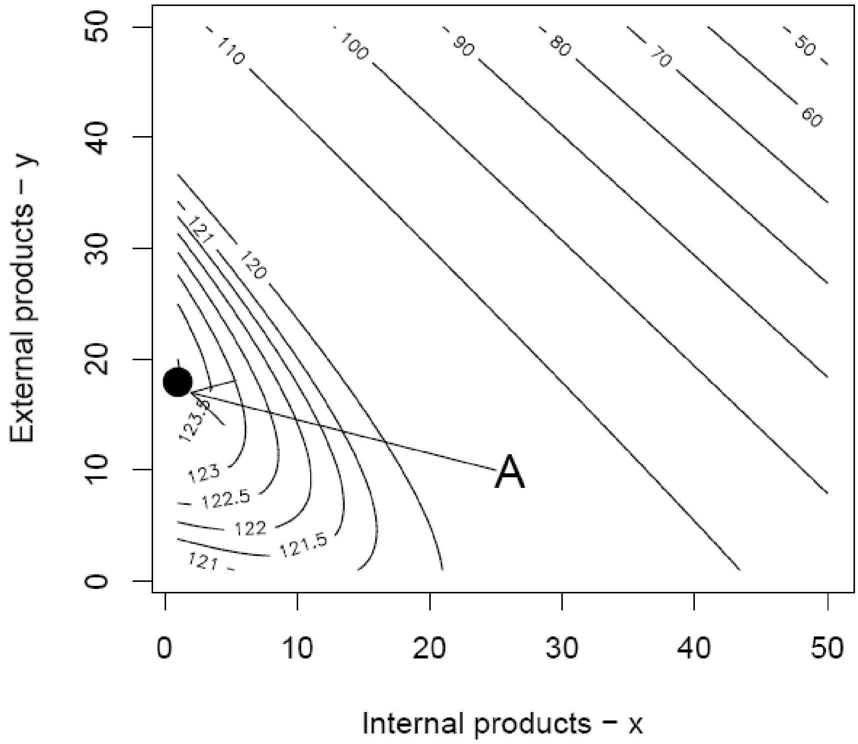


Table 3: Variations in normalized monetary yield achievable through production system scheduling optimization at different coopetition intensity levels δ.

δ	*y*	Max f (*x*, *y*)
0,75	32	1,12
0,70	30	1,09
0,65	28	1,07
0,60	25	1,04
0,55	22	1,02
0,50	18	1

This remark can be clarified by considering Table 3, which displays the result of variations in the level of δ. As mentioned above, δ is an exogenous parameter representing the proportion of line production time devoted to producing products of coopetitors. In other terms, setting δ at levels closer to 1 means the company is heavily committing to an intense coopetitive production strategy, whereas setting δ at near zero levels means the company is scarcely engaging in coopetitive production activity[10]. Table 3 shows that if we normalized to 1 the maximum yield achievable by a production-based coopetitive system when the company coopetition strategy set δ at 0.5 (thus equally splitting production time between internal production and production for coopetitors, or moving on the bisector in Figure 3, we would have an optimal variety level of coopetitors' products of 18 different products running on the company's production lines per week. If the company were to increase its coopetition commitment by increasing δ by 5%, setting $\delta = 0.55$, then the optimum number of external products would increase to 22, and the yield achieved by the company with its production line thus scheduled would increase by 2%. In the same line, by bringing coopetition to a very high level of intensity, for example by setting δ at 0.75, the company, by setting y at 32 external products, would find its yield level grow by about 12% with respect to the fifty-fifty naïve, balanced production time allocation between internal and external products. This sensitivity analysis over δ points out that a strong commitment for coopetition taken at strategic level (and therefore as an exogenous decision with respect to the implementational decision of production line scheduling) should be matched by a matching commitment for coopetition at the functional and operational levels, lest the company end up moving along suboptimal implementation paths and fail to fully harvest the potential benefits of coopetition.

DISCUSSION AND CONCLUSION

In their seminal work on coopetition, Brandenburger and Nalebuff advocated a new and challenging managerial mindset by leveraging the notion of complementarities between actors of the value net. Since then a large number of scholars have conducted empirical and theoretical research on coopetition[11]. However, it is here argued that the concept of complementarity that lies at the heart of the concept of coopetition has been largely neglected in the literature on coopetition. Conversely, a formal treatment of the notion of complementarity has been developed in economics. This refers to the stream of research known also as "economics of complementarities" (Milgrom & Roberts, 1990, 1995), which has its roots in lattice theory (Topkis, 1978, 1995, 1998). The paper points out that advances in the field of research on coopetition can enrich the literature on the economics of complementarities, and vice versa. In particular, as the field of coopetition should move toward renewed approaches possibly employing more rigorous, formal methodologies (Padula & Dagnino, 2007; Walley, 2007), the apparatus offered by the economics of complementarities provides a conceptually fitting field. In a similar vein, research on coopetition can contribute to the debate on the applicability and limitations of the economics of complementarities approach as put forward in this paper (Gino & Warglien, 2004; Porter & Siggelkow 2000; Siggelkow 2002b). Based on this premise, the research question highlights the issue of complementarity in coopetition, with a twofold objective. First, based on the concept of complementarity as a grounding element in coopetition strategies, a situated, case-based model of coopetition strategy yield at a single partner level was

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[10] Indeed, for $\delta = 1$ the company would become a pure outsourcer, and for $\delta = 0$ it would be a pure internal player. Neither of these options is considered in this discussion, however, as they both make the situation degenerate towards pure solutions which transcend the focus of this paper on the unintended effects of coopetition strategies at single partner level.

[11] For a review see Dagnino & Rocco, forthcoming.

developed. Second, in the light of the formal treatment of complementarities developed in economics field, the study also tested the assumptions underlying this theoretical body of research over a coopetition application. In particular, the model tested the first condition embedded in the notion of complementarity (condition (1b) in the paper), which requires that the relationship between two complementary variables *x* and *y* hold for all levels of *x* and y. The model unveils the presence, being overlooked at the corporate, strategy making level, of threshold effects in the implementation of a coopetition strategy and which, in turn, inhibit the exploitation of the positive complementarities' effects, leading to a decrement of total economic yield.

The mathematical model is based on an extended field study conducted in a soft drinks producer, San Benedetto which over two decades engaged into a set of coopetitive relationships for coprodution, joint new product development and creation of new factories abroad (Bonel & Rocco, 2007). The model proposed in this paper present results both in terms of an empirically specified model (namely, whose parameters have been specified based on empirical data), resulting in the graph displayed in Figure 2, and in terms of a generic situated model (namely, one where parameters are of a more generic nature, but coherent with real examples and data: this model has a more general validity than the empirically specified one), resulting in the graph displayed in Figure 3. Both model instances describe the benefits of a production-based coopetition strategy in terms of the economic payoff deriving from utilizing a production line for producing both internal and external (coopetitors') products. To reap the benefits of coopetition, San Benedetto must balance and optimize production of internal and coopetitor's products. The longitudinal case study pointed out the employment of a "fair heuristic" for optimization at the operational level. In other words, at the shop floor managers tried to equally satisfy internal and coopetitor-related demand. The model demonstrates the inefficiency of such heuristic, the application of which is to a large extent caused by a lack of coherent and interwoven decision making at the corporate and operational levels. For these reasons, the paper advocates the adoption of simulation techniques to support managerial decision making in face of the complexity raised by the implementation of coopetitive strategies.

Results import both empirical and theoretical implications. As for theoretical aspects, being situated, the model employs an empirical perspective to analyze complementarities' effects in coopetition. In this sense the model is built so as to describe a concrete situation in which optimization of coopetition-related complementarities concurrently takes into account realistic production issues which the traditional apparatus of the economics of complementarity approach did not (Milgrom & Roberts, 1995). This effort represents a theoretical advance with respect to the previous coopetitive literature as it proposes a rigorous, formal approach to coopetition issues in line with the advocated contamination between the field of coopetition and the economics of complementarities. Specifically, the study demonstrates that coopetition is not beneficial *ad libitum*. In fact, the relationship between two variables *x* and *y* does not hold for all levels of *x* and *y* (in the paper, condition (1b) for complementarity) but displays a threshold level in the variables, after which yield starts declining. Once the organization has committed itself to a certain level of collaboration with the external partner, the benefits of coopetition begin to unravel, if the variables reach a threshold. The model also points out another fundamental result: coopetition requires coherence at all firm's levels. Once the corporate level has defined it will engage into a coopetitive strategy, functional and operational levels should harmonize the new strategic address within the boundaries of the existing organization. This may imply a re-allocation of priorities and the identification of new rules of behaviour so as to achieve the benefits embedded in the coopetitive strategy. In our example, once the organization has committed itself to a fixed amount of time for collaboration with the partner (ie: has taken a strategic decision about coopetition), the operational level risks to incur into suboptimal decision making if it tries to keep a balanced development path between internal and coopetition-related production. The *ex-ante* decision to devote a certain amount of time to produce external products must be rolled out coherently and implemented at the shop floor. Once the level of coopetition has been chosen (e.g., 70% of the working time must be devoted to producing for the coopetitors), the fair heuristics (e.g., producing an equal number of batches both for San Benedetto and for coopetitors) leads to sub-optimal results when a threshold in complexity at production level is reached.

On the managerial side, the study unveils the existence of potential negative effects of coopetition. This situated model suggests that managers should be wary of the shaping of the complementarities embedded in their coopetition strategies, so as not to incur into threshold effects over the complementary variables making up their strategy which might depress rather than enhance value creation. The paper emphasizes that the literature has so far mainly focused on the potential huge benefits that can be harvested by engaging into coopetition strategies leveraging complementarities between firms. Threats have been identified as well to the extent interests' structure changes so as to private interests take over the alliance's interests (Gulati, Nohria, Zaheer 2000; Yoshino, Rangan 1995). Nonetheless, the study endorses a more careful analysis of the negative effects elicited by coopetition at the single firm's level, as coopetition increases internal complexity which, in turn, may raise unintended effects. In our case, complexity endorsed by working simultaneously for internal and external demands percolates through the whole organization. It is mainly at the lower hierarchical level that operational issues of coopetition become tangible. In general, firm's strategy and structure are linked to one another and they should change in a coherent fashion (Chandler 1962). However, such a change cannot be left to chance or spontaneous adaptation lest negative effects take over the planned benefits sought by the new strategic address. With this regard, cognitive scientists have disclosed limits of spontaneous coordination typically affecting managerial behaviour, for example letting a biased behaviour emerge which is attached to the notion of *coordination neglect* (Heath & Staudenmayer, 2002). Cognitive studies demonstrate that people tend to focus on single, specific components of a tightly interrelated set of capabilities, rather than consider and act on the big picture; this behaviour is referred to as "component focus" bias (Heath & Staudenmayer, 2002). Furthermore, when individuals attempt to reintegrate a specific piece of task into the big picture, they often fail to use a key mechanism for integration: ongoing communication. Individuals exhibit inadequate communication because a so-called 'curse of knowledge' makes it difficult to take the perspective of another and communicate effectively. This curse of knowledge occurs more often among specialists, who in turn find it especially difficult to communicate with each other (Heath & Staudenmayer, 2002). Coordination neglect synthesizes both component focus and inadequate intrafirm communication. Relating this behavioural field of study to coopetition, this paper argues that corporate level must gain awareness about the complexity of managing coopetition through the whole organization, from the strategic level, down to the shop floor, and especially manage the organizational and decisional processes accordingly at all levels. The corporate level should be aware of these behavioural limits and act accordingly so as to introduce suitable coordination mechanisms for the governance of coopetition within the organization. In addition, situated models like the one here developed, can support managerial learning and decision making. Their usefulness is evident when a high number of variables must be taken simultaneously into account, as in the case of coopetition.

With regard to the limitations of the current study, the structure embedded in this model was developed on the basis of extensive research in the production system of a soft drinks producer engaged in coopetition. Nonetheless, it simplifies the real world phenomena as directly observed by the authors. In particular, it was that assumed set up times (alpha) be linear in the number of total products and marginality to be linear in the number of products. Managers helped us in verifying these limitations and making the model assumptions feasible. With regard to δ (the amount of time devoted to produce for the coopetitor) in the model this parameter was considered as an *a priori* decision, resulting from the strategic agreement between the two partners at the beginning of the yearly coopetition-detailing contract for coproduction. Its value is fixed exogenously with respect to the model, which is focused on the implementation moment of a pre-set coopetition strategy. At the operational level the production scheduling must adjust to δ and establish the optimal mix of internal (x) vs. coopetitors' (y) products to deliver. Although this assumption reflects to some degree the firm's strategy, the current model with δ stretched to its upper bound indicates that San Benedetto would reach its highest monetary payoff if it turned into a dedicated manufacturer for its coopetitors. Such a conclusion, although consistent in mathematical terms, is in conflict with the goals pursued through the same coopetition strategy of the firm, which was aimed at reaping the synergies between a flexible manufacturing bottling system and product variety and towards ensuring the company's survival as an independent entity. The paper tries to overcome this intrinsic limitation of the model by fixing upper and lower boundaries for δ so that the strategy is not allowed to degenerate into extreme cases which the company would not take into account anyway. Further study is intended to pursue a number of extensions to the model. In particular, future research intends to gear the model towards analyzing the design (ie: what coopetition conditions should we set up?) rather than the implementational conditions of a pre-designed coopetition strategy (ie: given the coopetition level, how can we optimize the firms' yield?). This new model will further remove the assumption about exogenous δ (although a model with δ being exogenous was in fact developed and results did not change). The level of coopetition would be decided endogenously, as a function of x and y. Delta being endogenous, the variability hypothesis on marginality levels could also be encompassed and be viable in the model, as a result of coopetition conditions negotiations. Such an improvement is ongoing. Preliminary results allows to draw conclusions similar to those obtained in the model here presented with δ exogenously fixed. Furthermore, further research is intended to run the model at different times in the history of the coopetition strategy of the company, over same manufacturing technology applications, so as to control for situations in which the firm is engaged in single-partner, and/or multiple partner coopetition.

From the theoretical view point, a further exploration of the limits of the classic, supermodularity-based analysis of complementarities in coopetition is considered to be interesting. As stated above, it appears that the coopetition field is extremely well-suited to the application of the economics of complementarities approach. The latter's apparatus would allow coopetition researchers develop a more rigorous and formal approach to the study of coopetition effects. And yet, limitations of such apparatus must be overcome so as to adapt the economics of complemetarities to real-world managerial settings. In this paper we tackled the first of the three main limitations of the economics of complemetarities. This paper advocates for further research about the other two kinds too, namely contextual complementarities (seminal work is from Porter & Siggelkow, 2000) and frustrated systems, a term first put forward in managerial setting and investigated by Gino and Warglien (2004). As Porter and Siggelkow (2000) show, complementarity does not emerge in the same way in whatever firm it were applied, and differences in context of application do impinge on the results. This means that firms implementing the same system of complementarities, other strategic or organizational variables notwithstanding, will obtain different results. Future studies on coopetition should focus on the role of context in this strategy, and coopetition models in particular should focus on "contextuality effects". Finally, the development of models on systems of complementarities in which frustrated systems are present seems to be particularly promising. Frustrated systems encompass a very common class of complementarity settings, where conflicting and complementary practices inextricably coexist making it difficult for actors to find optimal solutions to interactions. This kind of methodology allows for a dynamic view to interactions (positive and negative ones), and the treatment of a high number of variables, which would allow for modeling complex strategies and their effects.

A more thorough understanding of the role, behavior and effect of complementarities in coopetition could add a fresh perspective to this field, as well as contribute to a more fitting view to complementarities as emerging in a managerial, rather than economic setting. A better grasp of the workings of complementarities and of the methodologies to study them would also help managers improve their strategizing abilities with respect to coopetition, as well as help them monitor strategy implementation and management.

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