Modeling Strategic Complementarity and Synergistic Value Creation in Coopetitive Relationships

Vik Pant[1(✉)] and Eric Yu[1,2]

[1] Faculty of Information, University of Toronto, Toronto, Canada
vik.pant@mail.utoronto.ca, eric.yu@utoronto.ca
[2] Department of Computer Science, University of Toronto, Toronto, Canada

Abstract. This paper proposes an approach for modeling and analyzing strategic complementarity in software businesses. The primary research objective is to develop an approach for representing and reasoning about synergistic value creation in software enterprises and ecosystems. This agenda is based on the increasing importance of complementarity as a concern within software organizations and their networks. It recognizes the prevalence of coopetition, as a common practice, in the software industry where businesses cooperate and compete simultaneously in open source communities, standards-setting bodies, and software ecosystems. It focuses on complementarity since it is a critical motivator for coopetition among software businesses. This study offers an approach for comparing alternate combinations of software products for assessing their abilities for synergy creation with reference to the concept of added value. It evaluates the sufficiency of this approach by applying it to an industrial case study from management literature. It also identifies a direction for future research for this line of inquiry.

Keywords: Complementarity · Coopetition · Software business · Strategy · Synergy

1 Introduction

Software enterprises and ecosystems rely on simultaneously cooperative and competitive relationships to achieve their collective as well as individual business objectives. It is common for software businesses, from global conglomerates to nascent startups, to engage in coopetitive behaviors towards each other. Such behaviors can be observed in dealings between software businesses in open source communities, standards-setting bodies, and software ecosystems [1]. Moreover, software businesses coopete with each other individually as well as through their partnerships and alliances with other firms – which are themselves coopetitive. Therefore, such software ecosystems [2], partner networks and alliance constellations have multifaceted relationships with each other where cooperation and competition exist concomitantly at the individual and collective levels. Furthermore, coopetition between enterprises can only be expected to increase as larger numbers of enterprises transform themselves from pipeline-driven business models to platform-oriented business models. This is because a key contributor to the

A. Ojala et al. (Eds.): ICSOB 2017, LNBIP 304, pp. 82–98, 2017.
https://doi.org/10.1007/978-3-319-69191-6_6

growth of coopetition in the software industry is the presence of complementarity between many software businesses.

Software business (SB) research focuses on the corporate strategies of software companies. It is concerned with the study of business models of software enterprises to identify their sources of value creation for organizational stakeholders. SB frameworks are intended to explain various facets of a software business such as its product strategy, revenue logic, distribution model, and service implementation model [3]. Such frameworks can be applied to examine different types of software businesses including "pure software product business, enterprise solution system business, and software service business" [4]. These frameworks are designed for analyzing software businesses and hence they are useful for understanding the "relation between a business model, business logic and business strategy" of software companies [5]. Complementarity motivates coopetition, which is an increasingly common feature of inter-organizational relationships between software enterprises and ecosystems. Thus, by illuminating this important concept, this paper furthers understanding into business models and strategies of software businesses.

The rest of the paper is organized as follows. The next section of this paper outlines our research objectives and expected contributions to the study of complementarity. It lists the core facets of strategic complementarity that must be accommodated by any framework that is designed to support the analysis of synergy. The third section presents a model of strategic complementarity and synergistic value creation that is based on an industrial case study from the software industry. The fourth section discusses the key facets of strategic complementarity that are relevant for modeling and analyzing it. The fifth section covers future work and conclusions. The references in this paper are listed in the sixth section.

2 Analyzing Strategic Complementarity Between Actors

Complementarity is a key characteristic of coopetition [8]. Complementarity is also referred to as synergy which is colloquially described as the whole being greater than the sum of its parts [6]. Tee & Gawer [9] assert that "complementarity refers to the combined returns from the combination of two or more assets, with some combinations resulting in higher value creation than other combinations." Similarly, Kyriakopoulos & Moorman [10] claim that "complementarity refers to the degree to which the value of an asset or activity is dependent on the level of other assets or activities." Milgrom & Roberts [11] credit Edgeworth for introducing this concept into economics, where it has been studied extensively. They note that the notion of complementarity can be applied to inputs, such as goods and services, as well as activities [12]. In their influential work on coopetition theory, Brandenburger & Nalebuff explain that a "complementor" is an actor that makes a focal actor more valuable/attractive to a buyer/seller when that buyer/seller can buy/sell from/to both actors rather than when it can only do so with one of them alone [13].

The effects of complementarity can be observed in a variety of enterprise functions ranging from marketing and sales to production and distribution. Examples of the former include goods/services that are regarded by consumers as being more valuable together than separately. For instance, Barquera et al. [14] and Ng et al. [15] claim that coffee and milk are complements. Examples of the latter include economies of scope wherein it is cheaper for a firm to manufacture/deliver goods/services jointly in comparison to manufacturing/delivering each good/service individually. For instance, Tsuji [16] asserts that economies of scope can be found in “department stores which offer consumer loans” and “electric appliances makers which produce PCs”. Complementarity is a key motivation for participation in software ecosystems by rival vendors.

Following [29], we distinguish between the concepts of *value added* by an actor, and *added value* of an actor in a multi-party economic relationship. Reasoning about strategic complementarity between actors requires the ability to analyze three main factors which are resources/assets/objects, value added by each actor, and added value of each actor. A resource/asset/object refers to an entity associated with some value, benefit, or utility for a stakeholder. Value added by an actor refers to the incremental addition of some value, benefit, or utility by that actor. Added value of an actor refers to the worth of that actor in terms of value, benefit, or utility creation in a multi-party economic relationship. In analyzing complementarity, the notions of value added and added value are viewed from the perspective of the stakeholder that is the beneficiary of synergy.

Modeling is widely used in IS engineering, and recently has been extended to deal with strategic management (SM) concerns. IS researchers have incorporated theories from SM into modeling frameworks to reason about strategic decisions [7, 31]. For example, in our earlier work, we analyzed inter-organizational competition that resulted from resource conflicts [6]. Similarly, Santos [34] proposes Power Models that are useful for understanding the relationships between different actors in an ecosystem by applying ideas about power from the SM literature. Driven by their proliferation in industrial practice and prominence in SM literature – ideas from coopetition theory are starting to appear in IS publications. However, complementarity, which is a prime driver of coopetition, has not been integrated into modeling frameworks in a structured and systematic manner. The absence of such integration “make it difficult for requirements engineers to validate low-level requirements against the more abstract high-level requirements representing the business strategy” [32]. In this paper we use modeling to analyze strategic complementarity.

3 Example: Complementarity Between Windows and Pentium

3.1 Analyzing Strategic Complementarity in the Wintel Alliance

A widely-studied example of complementarity and coopetition is the case of Wintel (i.e., Microsoft Windows operating system on Intel x86 chipsets) [17]. Throughout the 1990s, Microsoft and Intel simultaneously competed and cooperated with each other [18]. They cooperated to achieve their common goal of establishing Wintel as the de facto standard in personal computing [19]. This joint objective comprised of enlarging the market for Windows on x86 by competing with vendors of substitute products, such as Apple and Motorola [20]. However, Microsoft and Intel also had their private goals of maximizing their individual shares of the collective value created by the Wintel alliance [21]. This created a, "kind of interfirm dynamics which allow the competing firms involved to manage a partially convergent interest and goal structure" [22].

Brandenburger & Nalebuff [13] suggest that complementarity between Windows and Pentium motivated the coopetitive relationship between Microsoft and Intel. The basic reason for the presence of this complementarity was that a customer (i.e., PC user), with a specific set of requirements, could do more by using these products together rather than separately. For example, a PC user could get better performance in Windows with Pentium because Intel had optimized that chipset for Windows and Microsoft had implemented the MMX multimedia instruction set from Intel into Windows [18]. If this user chose a different operating system (e.g., Linux) on Pentium or Windows on a different chipset (e.g., K6) then that user would have foregone the performance improvements that stemmed from the co-optimization of Windows and Pentium.

However, while Wintel offered performance advantages to a PC user (compared to substitutes of Windows and Pentium) it also locked that user into a relationship with proprietary vendors. Microsoft and Intel charged premium prices and this translated into higher costs for that user. Conversely, if this user chose a different operating system or chipset then they would have saved money but would not have benefited from the performance advantages of Wintel. This was just one of many tradeoffs that vendors (such as Microsoft, Intel, Apple, and AMD) had to analyze to develop persuasive value propositions for their target customers.

As this example indicates, reasoning about complementarity requires the ability to evaluate the objectives of an actor (e.g., PC user), the options that are available to meet those objectives, and the impact of those options on those objectives. Each alternative can impact the satisfaction or denial of an actor's goals differently since there are trade-offs between those options. The satisfaction of an objective leads to realization of benefits for an actor while its denial impairs such benefit realization. Therefore, to understand the presence and extent of complementarity between entities the individual and collective effects, of those entities, on value creation must be compared. This can be done using text, as was done in this sub-section, as well as by using models, as is done in the following sub-section.

3.2 Reasoning About Strategic Complementarity in the Wintel Alliance

In this paper, we use two modeling languages, i* and e3value, in combination to analyze strategic complementarity between Microsoft Windows and Intel Pentium. i* is explained by Lucena et al. in [27] and e3value is explained by Souza et al. in [28]. These authors depict metamodels of i* and e3value in [27, 28] respectively. i* (distributed intentionality) is a socio-technical modeling language that can be used to represent the intentional structure of an actor as well as its strategic relationships with other actors. It is useful for analyzing complementarity because it supports comparing the impact of alternatives on objectives via links between means and ends.

Figures 1a, 1b, and 1c show the impact of different combinations of operating systems and chipsets on the satisfaction of various objectives of a home user of personal computer (PC). Figure 1d presents a composite model of alternatives available to a home user for personal computing. i* is a goal modeling language and the main conceptual entities in i* are goals, tasks, resources, and softgoals. Within the scope of each actor, a *goal* is a state of affairs that an actor intends to achieve in the world. For example, in Figs. 1a, 1b and 1c, the goal of a home user is to buy a PC. A *task* is a means for achieving an end which refers to satisfying a goal. For example, in Figs. 1a, 1b and 1c, a home user can buy Windows on Pentium, Windows on other chipset, or other operating system on Pentium to satisfy its goal of buying a PC. A *resource* is a physical or informational object that is required to achieve some goal or perform some task. For example, in Fig. 1a, a home user procures Pentium from Intel and obtains Windows from Microsoft.

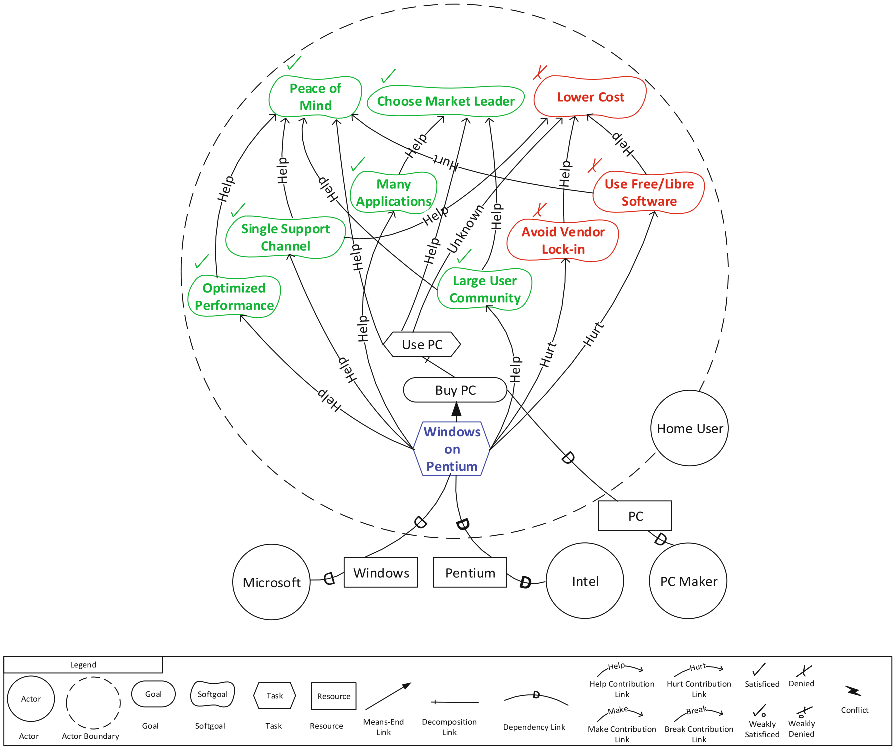

Fig. 1a. i* SR diagram showing adequacy of Wintel.

A *softgoal* is a quality objective or nonfunctional requirement that does not have well defined satisfaction criteria. The fulfilment of a softgoal is judged subjectively from the perspective of an actor through elaboration and refinement. For example, in Figs. 1a, 1b and 1c, the requirements of a home user are represented as softgoals. This is because their satisfaction is judged subjectively from the perspective of that home user. Figure 1a shows those requirements that are satisfied/denied if the home user chooses Windows on Pentium. Figure 1b shows those requirements that are

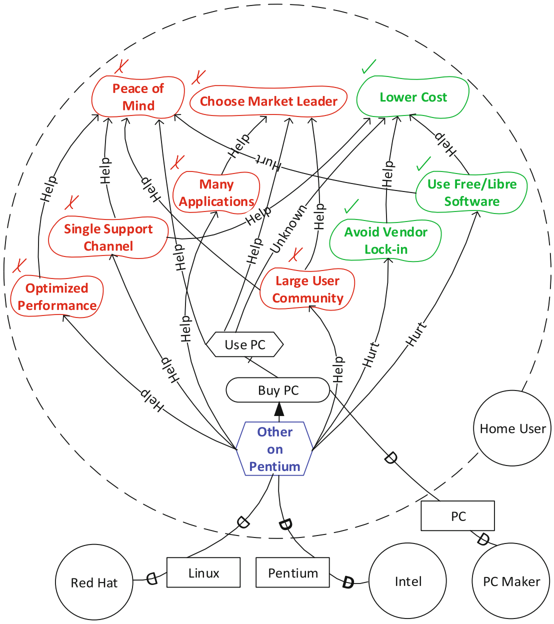

Fig. 1b. i* SR diagram showing adequacy of other operating system on Pentium.

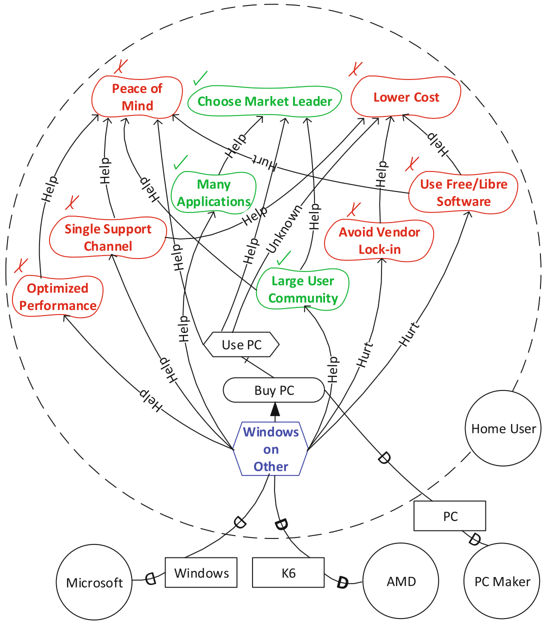

Fig. 1c. i* SR diagram showing adequacy of Windows on other chipset.

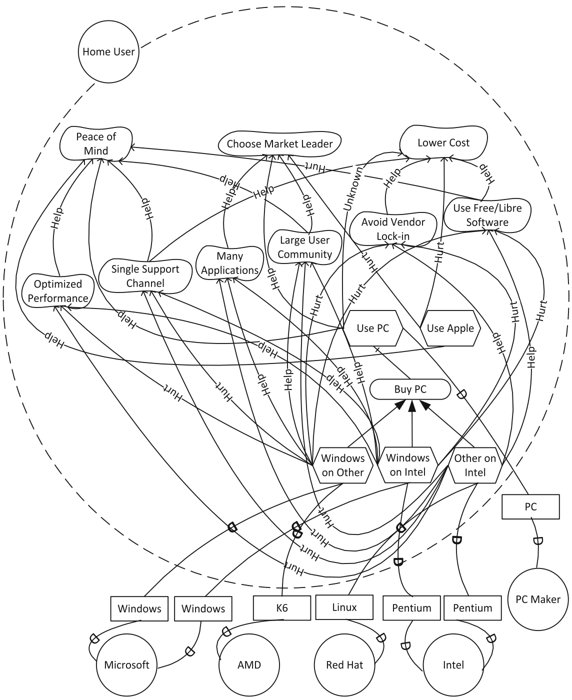

Fig. 1d. i* SR diagram showing all three alternatives.

satisfied/denied if the home user chooses an operating system other than Windows (e.g., Linux) on Pentium. Figure 1c shows those requirements that are satisfied/denied if the home user chooses Windows on a chipset other than Pentium (e.g., K6).

These entities are connected via means-ends links, decomposition links, dependency links, and contribution links. *Means-ends links* relate a goal to one or more tasks such that the completion of any of those tasks achieves that goal. For example, in Figs. 1a, 1b and 1c, Windows on Pentium, other operating system on Pentium, and Windows on other chipset are examples of alternate means that satisfy the same goal of buying a PC. *Decomposition links* relate a task to other elements such that the fulfilment of all those elements is required to perform that task. For example, in Figs. 1a, 1b and 1c, a home user needs to buy a PC before it can use that PC. Contribution links denote various types of impacts (such as help, hurt, etc.) that different entities have on softgoals. For example, in Fig. 1a, buying a PC that runs Windows on Pentium helps a home user benefit from optimized performance as well as access to a large user community.

Dependency links are used to express the intentional relationships between actors based on the goals, tasks, resources, and softgoals that an actor depends on from another actor. An actor that depends on another actor is termed a depender, an actor on which another actor depends is termed a dependee, and the object of the dependency between actors is termed a dependum. For example, in Fig. 1a, a home user depends on

Intel to procure Pentium and Microsoft to obtain Windows. In the diagrams in this paper, we have omitted dependencies from the vendors to the home user (i.e., for money) to simplify the visual presentation and interpretation of these diagrams.

A comparison of Figs. 1a, 1b and 1c shows that Windows on Pentium satisfies the overall requirements of a home user better than Windows on other chipset or other operating system on Pentium. Thus, Windows and Intel are more valuable together for a home user than Windows and Pentium separately because neither Windows and a different chipset nor another operating system and Pentium can meet a home user's PC requirements as optimally as Windows and Pentium can jointly. This demonstrates the presence of complementarity between Windows and Pentium and points out the reasons for the existence of that complementarity. It should be noted that while these i* diagrams allow us to depict the presence of complementarity between Windows and Pentium—they do not allow us to depict the magnitude of surplus from that synergy.

e3value is a value modeling language that can be used to represent networks that are setup to facilitate economic exchanges between organizations. It is useful for analyzing complementarity because it can be used to compare the individual and collective value creation effects of entities. In e3value, the main conceptual entities are actors, value objects, value ports, value interfaces, value transfers, value transactions, and value activities.

An *actor* is an economically independent entity (e.g., Microsoft) that transfers *value objects* (e.g., Windows) to other actors (e.g., home user) in return for objects (e.g., money) of benefit/utility from them. *Value ports* (e.g., catalog) are used by an actor (e.g., Microsoft) to offer (e.g., Windows) or demand (e.g., money) value objects from other actors (e.g., home user). *Value interfaces* are groupings of value ports (e.g., sale) that represent economic reciprocity such that all the value ports in a value interface exchange value objects or none of them do. *Value transfers* are used to connect two value interfaces (e.g., buy, sell) and *value transactions* (e.g., procurement) group value transfers such that all the value transfers in a value transaction occur or none of them do. Actors perform *value activities* (e.g., sell software) to create economic profits.

In this paper, we use a slightly extended e3value notation, in Figs. 2a and 2b, to analyze the magnitude of complementarity between Windows and Pentium. The concepts of *willingness-to-pay (WP)* and *opportunity cost (OC)* are relevant for analyzing complementarity. WP refers to the maximum resources (e.g., money) that an actor (e.g., home user) will voluntarily relinquish in exchange for another resource (e.g., operating system, chipset). OC refers to the minimum resources (e.g., money) that an actor (e.g., Microsoft, Intel) will voluntarily accept to relinquish another resource (e.g., Windows, Pentium). The logics of WP and OC hold because a rational and self-interested actor cannot be expected to give up a more valuable resource in exchange for a less valuable resource but that it will gladly give up a less valuable resource in exchange for a more valuable resource [29].

We have extended the standard e3value notation slightly by inscribing the identifiers of actors, market segments, and value activities within their respective boundaries. We have also specified the content of a value exchange above the arrow that represents it. The value can specify a range (expressed as inequalities) rather than a fixed quantity. Figure 2a shows the separate value constellations of Intel and Microsoft wherein each of these vendors provide their products, Pentium and Windows, to a home user

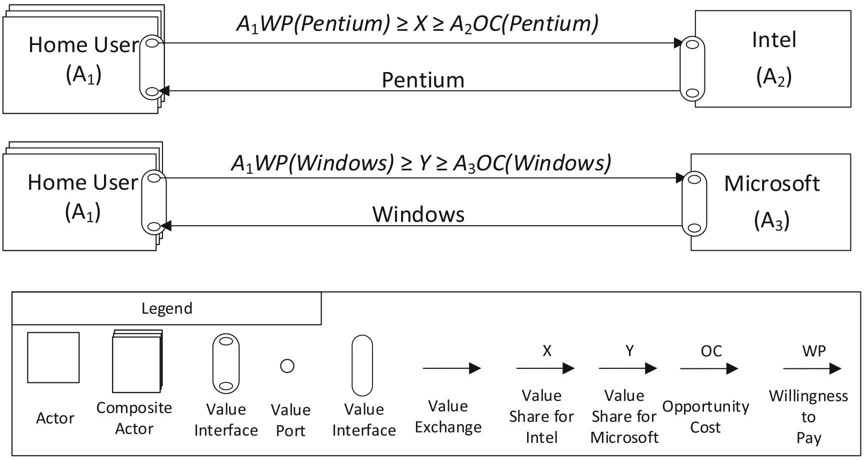

Fig. 2a. e3value diagram of separate value constellations of Microsoft and Intel.

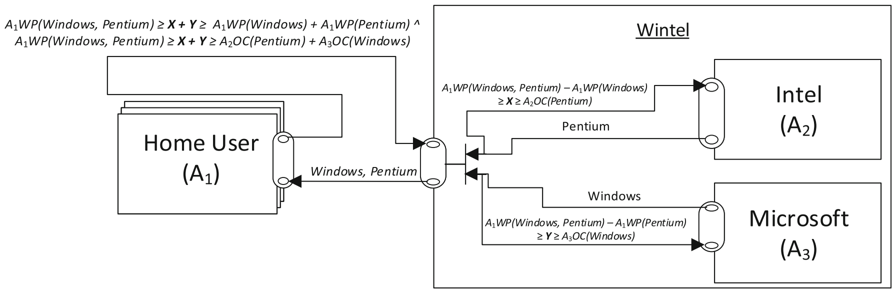

Fig. 2b. e3value diagram of Wintel's value constellation.

separately. The upper sub-diagram in Fig. 2a shows that Intel delivers a Pentium chip to a home user who pays Intel an amount that is less than or equal to that home user's WP for Pentium and is greater than or equal to Intel's OC for selling Pentium. The lower sub-diagram in Fig. 2a shows that Microsoft delivers Windows operating system to a home user who pays Microsoft an amount that is less than or equal to that home user's WP for Windows and is greater than or equal to Microsoft's OC for selling Windows.

Figure 2b shows the joint value constellation of Wintel wherein the home user gets the Microsoft operating system and the Intel chipset together (i.e., Windows on Pentium). In this case the WP of a home user for Windows and Pentium together is greater than the sums of their WP for Windows and Pentium separately. This is the case, because comparing Figs. 1a, 1b and 1c leads to the conclusion that Windows and Pentium are complements such that a home user is willing to pay more for an offer that combines their value propositions than one that keeps them apart. Both Windows and Pentium are more beneficial to a home user and offer greater utility to that home user when they are together than when they are separate. This difference between a home user's WP for Windows as well as Pentium jointly and the sum of a home user's WP for Windows as well as Pentium separately can be regarded as surplus from synergy. This is additional value that is present within a joint value constellation of Microsoft and Intel but is absent from the individual value constellations of these vendors.

In the scenario depicted in Fig. 2a, calculating the amount of value that is acquired by Microsoft and Intel in their separate value constellations is relatively straightforward. This is because the upper bound of value that Microsoft and Intel can appropriate individually is constrained by a home user's WP for their respective products alone (i.e., Windows, Pentium). In Fig. 2b, however, calculating the upper bound of value that Microsoft and Intel can appropriate from their joint value constellation is relatively complicated. This is because both Microsoft and Intel can stake their respective claims on the surplus from synergy that is generated by their partnership. While neither Microsoft nor Intel will, under most circumstances, voluntarily accept an amount that is lower in value than their OC for Windows and Pentium respectively – the presence of surplus creates the possibility for them to appropriate an amount that is greater in value than a home user's WP for Windows and Pentium respectively.

Added value is relevant for determining the upper bound on the amount of value that Microsoft and Intel can appropriate from for themselves from the Wintel constellation. The reason that this is the case is because if an actor appropriates an amount of value greater than this limit then the amount of value remaining for the other actors to appropriate becomes lower than their OCs. In such a case those other actors would be worse off by participating in such an economic relationship and they would be better off by abstaining from it [29]. This logic describes the paradox of joint value creation and individual value appropriation within coopetition wherein firms are "cooperating to create a bigger business 'pie,' while competing to divide it up" [13]. Hence, being able to analyze complementarity is a crucial requirement for managing coopetitive relationships.

Added value is calculated by subtracting the economic value of the relationship without the focal actor from the economic value of the relationship with all the actors [29]. The formulae for calculating added value is denoted in Fig. 2b above the arrows representing the value transactions from the composite actor, Wintel, to its constituent actors, Microsoft and Intel. These formulae above the inbound value transaction for Microsoft/Intel indicate the upper bound on the value that Microsoft/Intel can appropriate for itself from Wintel. Thus, added value is a home user's WP for Windows and Pentium (i.e., value of the economic relationship with all the actors involved) less that home user's WP for Pentium/Windows (i.e., value of the economic relationship without the focal actor). These formulae also specify the lower bound on the amount of value that Microsoft/Intel will voluntarily accept as their OCs for Windows/Pentium respectively.

As this modeling-supported reasoning shows, i* is useful for understanding the causes of complementarity while e3value is useful for determining the extent of complementarity. i* and e3value explain different aspects of strategic complementarity between actors and together they can represent more facets of synergistic value creation than either of them can depict alone. Specifically, "i* goal models complement the e3value models by revealing the strategic reasoning (i*) behind the value exchanges (e3value)" [25]. Due to such compatibility, i* and e3value have been used jointly to depict strategic relationships between actors in the scholarly literature [25, 26]. This is also consistent with the recommendation from Bleistein et al. [32] that, "depending on the needs, several languages can also be used together in a complementary way".

The steps for reasoning about the Wintel case can also be applied to analyze the complementarity between other software businesses and networks such as software ecosystems. The first step involves the development of actor and goal models using i* to explain the strategic rationales and strategic dependencies between software businesses and focal stakeholders. The second step involves comparing these models to identify the relative impact of each alternative on the satisfaction of stakeholder requirements. The third step involves the development of e3value models of separate and joint value constellations of software businesses to measure the magnitude of complementarity between them. The next section presents an abstraction of the concepts in this section to aid in the reuse of these steps. It focuses on the modeling of the concepts of value added by an actor in isolation and added value of an actor to a multi-party economic relationship.

4 A Method for Modeling and Analyzing Strategic Complementarity and Synergistic Value Creation

4.1 Value Added by an Actor in a Value Chain

Value added is an intuitive concept that is defined by [30] "as revenue minus the cost of purchased inputs." Consider Figs. 3a and 3b that show a market in which a consumer (A_1) buys a finished product (O_2) from a vendor (A_2) and that vendor (A_2) procures raw materials (O_1) from a supplier (A_3). A_2 performs an activity (C_1), by applying its competences and combining its resources, to transform O_1 (that it has procured from $A_{3)}$ into O_2. A_1 decides to buy O_2 from A_2 by compensating it with X resources since O_2 is useful for A_1. While the following exposition discusses the relationship between A_1 and A_2 – such a relationship holds likewise between A_2 and A_3. This is because, just as A_2 is a vendor that sells O_2 to A_1 which is its customer – similarly A_3 is a vendor that sells O_1 to A_2 which is its customer.

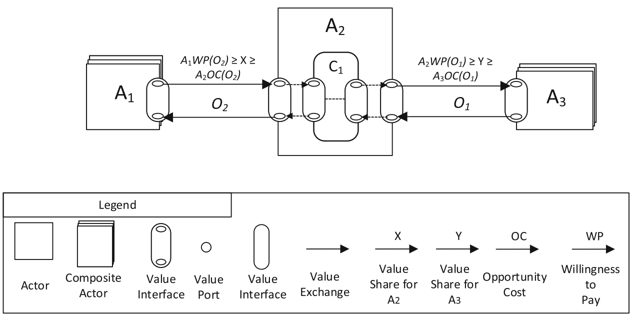

Fig. 3a. e3value diagram of A_2's value constellation.

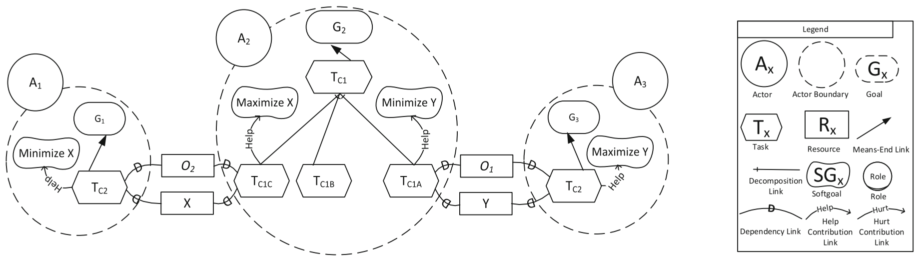

Fig. 3b. i* Strategic Rationale (SR) diagram showing willingness-to-pay and opportunity cost.

In this market, two economic factors impose an upper and lower bound on X/Y respectively. The upper bound is dictated by the customer (A_1/A_2) while the lower bound is determined by the vendor (A_2/A_3) such that X/Y is determined through a process of bargaining and negotiation between A_1/A_2 and A_2/A_3. Figure 3a denotes the upper/lower bounds in the formula above an arrow representing value exchanges, which are X and Y, between A_1 and A_2 as well as A_2 and A_3 respectively. In this example the value added by A_2 is X – Y. We focus on the relationship between A_1 and A_2 to discuss these upper/lower bounds on X but this logic is equally relevant in the relationship between A_2 and A_3.

The maximum amount of resources that A_1 is willing to pay A_2 is less than or equal to the maximum benefit, utility, or value that A_1 can obtain from O_2. This upper bound refers to the concept of '*willingness to pay*' that was discussed in Sect. 3. This WP is noted in Fig. 3a as $A_1WP(O_2)$. A_1 is unwilling to pay an amount higher than $A_1WP(O_2)$ because doing so would mean that A_1 would give away more resources for O_2 than what A_1 considers it to be worth. Conversely, however, A_1 is willing to pay A_2 an amount less than $A_1WP(O_2)$ for O_2 because that would mean that A_1 is underpaying A_2 by giving away fewer resources for O_2 than what A_1 considers it to be worth. A rational and self-interest seeking economic actor is willing to underpay for a resource because doing so creates a perceived surplus. However, that actor is unwilling to overpay for a resource because doing so creates a perceived deficit for that actor.

The minimum amount of resources that A_2 is willing to accept from A_1 is greater than or equal to the maximum amount of resources that A_2 can obtain from O_2 through an alternate use (e.g., selling it to someone else). This lower bound refers to the concept of '*opportunity cost*' that was discussed in Sect. 3. This OC is noted in Fig. 3a as $A_2OC(O_2)$. A_2 is unwilling to accept an amount less than $A_2OC(O_2)$ because doing so would mean that A_2 would get fewer resources by selling O_2 to A_1 than it can by applying it to some other use. Conversely, however, A_2 is willing to accept an amount from A_2 that is greater than $A_2OC(O_2)$ for O_2 because that would mean that A_2 is getting more resources for O_2 from A_1 than it would from the next best alternative use of O_2. Figure 3b shows the structure of such bargaining and negotiating between A_1/A_2 and A_2/A_3.

4.2 Added Value of an Actor to a Multi-party Economic Relationship

Added value is different from value added because while the latter represents economic margin (i.e., difference between revenues and purchased inputs), the former denotes the worth of a party in a multi-party economic relationship. In the context of a specific player, added value refers to the "value created by all the players in the vertical chain minus the value created by all the players in the vertical chain except the one in question" [29]. Consider Figs. 4a, 4b and 4c that show a market in which a consumer (A_1) buys two products from two vendors – O_1 and O_2 from A_2 and A_3 respectively. A_1 can use O_1 and O_2 individually (i.e., without each other) or it can use them jointly (i.e., with each other).

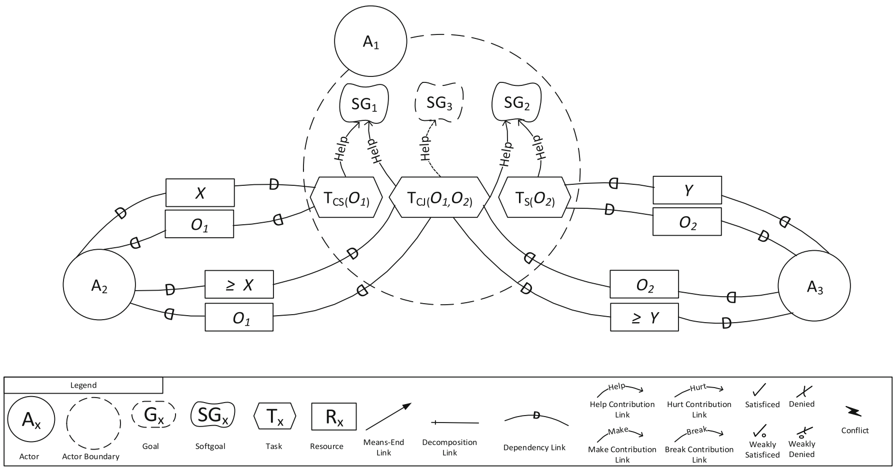

Fig. 4a. i* SR diagram of A_1 with complementarity between A_2 and A_3.

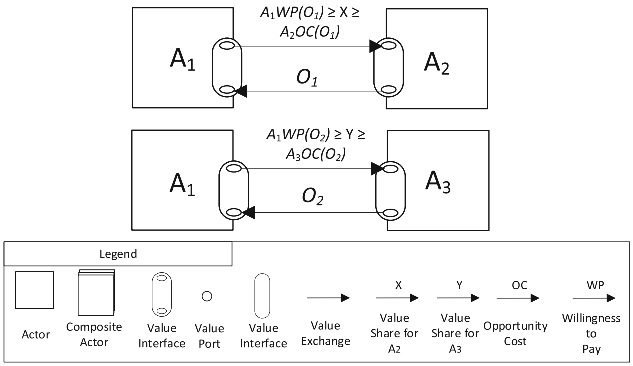

Fig. 4b. e3value diagram of A_1's value constellation with separate usage of O_1 and O_2.

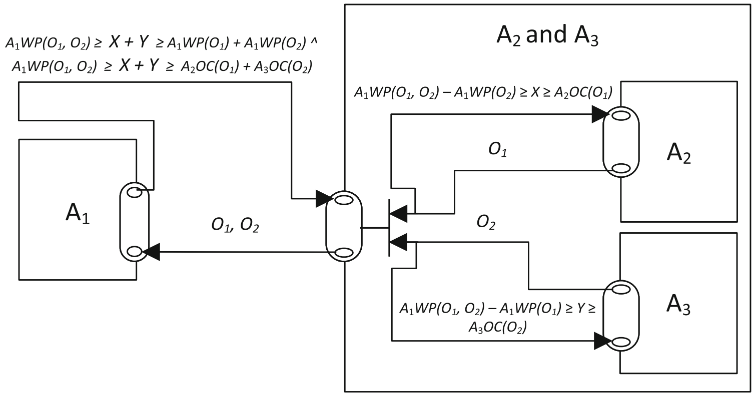

Fig. 4c. e3value diagram of A_1's value constellation with complementarity between A_2 and A_3.

Figure 4b shows a situation in which A_1 consumes O_1 and O_2 separately while Fig. 4c shows a situation in which A_1 consumes O_1 and O_2 jointly. Figure 4a shows both situations. Figure 4a shows the presence of complementarity between O_1/A_2 and O_2/A_3, which is an incentive for A_1 to use O_1 and O_2 jointly rather than separately. In Fig. 4a, A_1 is able to satisfy more objectives by using O_1 and O_2 together than by using either O_1 or O_2 separately. In a situation of complementarity, as depicted in Fig. 4b, it is not feasible to use the WP of A_1 for O_1 or O_2 as the upper bound on the value that their respective firms (i.e., A_2 and A_3) can appropriate from this joint value constellation. Rather, the presence of a surplus from synergy necessitates the calculation of the added values of A_2 and A_3 to determine the maximum amount of value that each firm can appropriate from this joint value constellation.

Complementarity exists in the case of joint usage of O_1 and O_2 because by using these products together the home user can satisfy more of its objectives than it can by using either O_1 or O_2 separately. Therefore, this home user is willing to pay a greater amount for the relatively higher utility or benefit that it can obtain this combined offering than that from using either of these products without the other. This presence of complementarity is indicated via the greater outbound value flow from the home user for O_1, O_2 in Fig. 4c compared to the sum of the outbound value flows from that home user for O_1 and O_2 in Fig. 4a. The difference between these value flows can be regarded as the surplus from synergy because it refers to an amount that is only present when O_1 and O_2 are together but is absent when O_1 and O_2 are separate.

The amounts of value, X and Y, that can be appropriated by actors, A_2 and A_3, is specified as a range because X and Y are dependent on each other. Since the total value that can be appropriated by all the actors is fixed, $A_1WP(O_1, O_2)$, then the more/less amount of value that is appropriated by an actor, A_2/A_3, reduces/increases the amount of value that is remaining for appropriation by another actor, A_3/A_2. As discussed in Sect. 3, if an actor, A_2/A_3, appropriates a greater amount of value than their added value then another actor, A_3/A_2, will only be able to appropriate an amount of value less than their opportunity cost. The presence as well as the magnitude of complementarity can be expressed and explained by using i* and e3value together in this way.

5 Conclusions and Future Work

In this paper, we proposed a modeling technique and method for articulating and analyzing strategic complementarity to aid in the understanding of business models and strategies of software businesses. The modeling technique offered by this paper is useful for understanding the presence of complementarity as well as the magnitude of synergy effects. We used an industrial case study from the literature to test our modeling method as well as to elicit decontextualized patterns to explain strategic complementarity. To further test the technique, we are conducting case studies in enterprise settings as well as in ecosystems and startup-ups.

References

1. Valença, G., Alves, C., Heimann, V., Jansen, S., Brinkkemper, S.: Competition and collaboration in requirements engineering: a case study of an emerging software ecosystem. In: 2014 IEEE 22nd International Requirements Engineering Conference (RE), pp. 384–393. IEEE, August 2014
2. Teixeira, J., Robles, G., González-Barahona, J.M.: Lessons learned from applying social network analysis on an industrial Free/Libre/Open Source Software ecosystem. J. Internet Serv. Appl. **6**(1), 14 (2015)
3. Rajala, R., Rossi, M., Tuunainen, V.K.: A framework for analyzing software business models. In: European Conference on Information Systems, pp. 1614–1627, June 2003
4. Väyrynen, K.: Software business in industrial companies: identifying capabilities for three types of software business. In: Proceedings of the 31st International Conference on Information Systems (ICIS), Saint Louis, MO (2010)
5. Vanhala, E., Smolander, K.: What do we know about business models in software companies?-systematic mapping study. Int. J. IADIS **11**(3), 89–102 (2013)
6. Pant, V., Yu, E.: Coopetition with frenemies: towards modeling of simultaneous cooperation and competition among enterprises. In: Horkoff, J., Jeusfeld, M.A., Persson, A. (eds.) PoEM 2016. LNBIP, vol. 267, pp. 164–178. Springer, Cham (2016). doi:10.1007/978-3-319-48393-1_12
7. Gordijn, J., Osterwalder, A., Pigneur, Y.: Comparing two business model ontologies for designing e-business models and value constellations. In: Proceedings of BLED 2005, 15 (2005)
8. Brandenburger, A.M., Nalebuff, B.J.: The right game: use game theory to shape strategy. Harvard Bus. Rev. **73**(4), 57–71 (1995)
9. Tee, R., Gawer, A.: Industry architecture as a determinant of successful platform strategies: a case study of the i-mode mobile Internet service. Europ. Manag. Rev. **6**(4), 217–232 (2009)
10. Kyriakopoulos, K., Moorman, C.: Tradeoffs in marketing exploitation and exploration strategies: the overlooked role of market orientation. Int. J. Res. Mark. **21**(3), 219–240 (2004)
11. Milgrom, P., Roberts, J.: Complementarities and fit strategy, structure, and organizational change in manufacturing. J. Account. Econ. **19**(2), 179–208 (1995)
12. Milgrom, P., Roberts, J.: Complementarities and systems: Understanding Japanese economic organization. Estud. Economicos **17**, 3–42 (1994)
13. Brandenburger, A.M., Nalebuff, B.J.: Co-opetition. Doubleday, New York (1996)

14. Barquera, S., Hernandez-Barrera, L., Tolentino, M.L., Espinosa, J., Ng, S.W., Rivera, J.A., Popkin, B.M.: Energy intake from beverages is increasing among Mexican adolescents and adults. J. Nutr. **138**(12), 2454–2461 (2008)
15. Ng, S.W., Mhurchu, C.N., Jebb, S.A., Popkin, B.M.: Patterns and trends of beverage consumption among children and adults in Great Britain, 1986–2009. Br. J. Nutr. **108**(03), 536–551 (2012)
16. Tsuji, M.: Envisioning the Japanese economic system in the 21st century in relation to economies of network. In: Schober, F., Kishida, T., Arayama, Y. (eds.) Restructuring the Economy of the 21st Century in Japan and Germany, pp. 15–36. Duncker & Humblot, Berlin (1999)
17. Gomes-Casseres, B.: How alliances shape competition. In: Shenkar, O., Reuer, J. (eds.) Handbook of Strategic Alliances, pp. 39–54. Sage, Newbury Park (2005)
18. Yoffie, D.B., Kwak, M.: With friends like these: the art of managing complementors. Harvard Bus. Rev. **84**(9), 88–98 (2006)
19. Gomes-Casseres, B.: Competitive advantage in alliance constellations. Strateg. Organ. **1**(3), 327–335 (2003)
20. Golnam, A., Sanchez, R., Ritala, P., Wegmann, A.: The why and the how of coopetition: modeling the in-centives and design of coopetitive value networks. In: A Focused Issue on Building New Competences in Dynamic Environments. Research in Competence-Based Management, 7. Emerald Group Publishing Limited, pp. 29–60 (2014)
21. Casadesus-Masanell, R., Yoffie, D.B.: Wintel: cooperation and conflict. Manage. Sci. **53**(4), 584–598 (2007)
22. Castaldo, S., Dagnino, G.B.: Trust and coopetition: the strategic role of trust in interfirm coopetitive dynam-ics. In: Dagnino, G.B., Rocco, E. (eds.) Coopetition Strategy: Theory, Experiments and Cases, pp. 74–100. Routledge, New York (2009)
23. Pijpers, V., Gordijn, J.: *e³forces*: understanding strategies of networked *e³value* constellations by analyzing environmental forces. In: Krogstie, J., Opdahl, A., Sindre, G. (eds.) CAiSE 2007. LNCS, vol. 4495, pp. 188–202. Springer, Heidelberg (2007). doi:10.1007/978-3-540-72988-4_14
24. Pijpers, V., Gordijn, J., Akkermans, H.: Business strategy-it alignment in a multi-actor setting: a mobile e-service case. In: Proceedings of the 10th International Conference on Electronic Commerce (2008)
25. Gordijn, J., Yu, E., van der Raadt, B.: E-service design using i* and e3value modeling. IEEE Softw. **23**(3), 26–33 (2006)
26. Ouyang, F., Zhao, H.: Business models optimization using e3value and i* modeling: taking knowledge resource website as an example. Manage. Sci. Res. **3**(2) (2014)
27. Lucena, M., Santos, E., Silva, C., Alencar, F., Silva, M.J., Castro, J.: Towards a unified metamodel for i*. In: Second International Conference on Research Challenges in Information Science, RCIS 2008, pp. 237–246. IEEE, June 2008
28. Souza, E., Abrahão, S., Moreira, A., Araújo, J., Insfran, E.: Comparing Value-Driven Methods: an experiment design. In: Second International Workshop on Human Factors in Modeling (HuFaMo 2016). CEUR-WS, pp. 19–26 (2016)
29. Brandenburger, A.M., Stuart, H.W.: Value-based business strategy. J. Econ. Manag. Strategy **5**(1), 5–24 (1996)
30. Lieberman, M.B., Garcia-Castro, R., Balasubramanian, N.: Measuring value creation and appropriation in firms: the VCA model. Strategic Manage. J. (2016)
31. López, L.C., Franch, X.G.: Applying business strategy models in organizations. In: Proceedings of the 7th International i* Workshop 2014, Thessaloniki, Greece, 16–17 June (2014)

32. Bleistein, S.J., Cox, K., Verner, J.: Modeling business strategy in E-business systems requirements engineering. In: Wang, S., Tanaka, K., Zhou, S., Ling, T.-W., Guan, J., Yang, D.-Q., Grandi, F., Mangina, E.E., Song, I.-Y., Mayr, H.C. (eds.) ER 2004. LNCS, vol. 3289, pp. 617–628. Springer, Heidelberg (2004). doi:10.1007/978-3-540-30466-1_57
33. Giannoulis, C., Zikra, I., Bergholtz, M., Zdravkovic, J., Stirna, J., Johannesson, P.: A comparative analysis of enterprise modeling approaches for modeling business strategy. In: 6th IFIP WG 8.1 Working Conference on the Practice of Enterprise Modeling (PoEM 2013), Riga, Latvia, 6–7 November 2013, pp. 193–204, (2013)
34. Santos, G.A.V.: A theory of power in software ecosystems formed by small-to-medium enterprises. Ph.D. Thesis (2016)