Information & Management 51 (2014) 762–773

Contents lists available at ScienceDirect

Information & Management

journal homepage: www.elsevier.com/locate/im

Digital systems and competitive responsiveness: The dynamics of IT business value

Amitava Dutta *, Hun Lee, Masoud Yasai-Ardekani

School of Management MSN 5F4, George Mason University, 4400 University Drive, Fairfax, VA 22030, United States

ARTICLE INFO

Article history:
Received 16 November 2012
Received in revised form 13 April 2014
Accepted 3 May 2014
Available online 14 May 2014

Keywords:
IT business value
Competitive dynamics
Response delay
Simulation modeling

ABSTRACT

The mechanics of competition involve *perception* and *reaction* to competitor moves. Both incur delays that can be reduced by digital systems. Using system dynamics and the Red Queen paradigm, we modeled the impact of IT investments on response delays and business value, with the following results: (a) value has significant transient components; (b) value depends on investment level and the relative delays of competitors; and (c) relative delays affect the first-mover advantage. These results show that when assessing the value of IT investments, it is important to consider (a) the temporal pattern of benefits, not just their total magnitude, and (b) the impact of *ongoing* moves by competitors.

> *"The ability to learn faster than your competitors may be the only sustainable competitive advantage." - Arie de Gues, Former Director of Corporate Planning, Royal Dutch Shell*

> *"An organization's ability to learn and translate that learning into action rapidly is the ultimate competitive advantage." – Jack Welch, former CEO General Electric*

1. Introduction

Consider the battle between FedEx and UPS for the overnight package-delivery market [62]. UPS historically had lagged behind FedEx in its use of information technology (IT). In 1989, over a period of several months, UPS made a major investment to upgrade its systems to FedEx's level. Subsequently, UPS surpassed FedEx with the introduction of its handheld Delivery Acquisition Information Device (DIAD), which integrated with its Maxitrac system. FedEx would not introduce its own version of the Maxitrac until 1993. In November 1994, FedEx was the first to use the World Wide Web to offer an online package tracking service. Six months later, UPS introduced the same service. In March 1996, UPS introduced its complete Web-shipping service. One year later, a similar FedEx service was introduced. During the mid-1990s, FedEx and UPS targeted warehousing and logistics services. The systems that FedEx designed for this application attracted big-name customers such as National Semiconductor and Laura Ashley. UPS was not sitting idly by and was implementing a similar solution, but its system was still two years behind that of FedEx. In fact, 1992 was the first year in which UPS spent more on IT than on transportation assets. These actions by two competitors—FedEx and UPS—illustrate some important aspects of how the business value of IT is realized by a firm in a competitive environment. First, value is not realized instantaneously, but over time, usually an appreciable period. Second, during this period, competitors usually do not sit idly by. They respond with countermoves, which can diminish the benefits realized by the firm.[1] Third, the speed with which competitors can respond to each other plays a crucial role in the realization of business value from IT investments. Last but not least, the business value of IT investments is determined only over the course of *many iterations* of firms observing and reacting to competitors, or what the strategy literature calls the Red Queen Theory[2] [22], referring to Lewis Carroll's *Through The Looking Glass* [9], in which Alice notices that she appears to be stationary even though she is running a race.

---

* Corresponding author. Tel.: +1 7039931779.
E-mail addresses: adutta@gmu.edu (A. Dutta), hleeb@gmu.edu (H. Lee), myasai@gmu.edu (M. Yasai-Ardekani).

[1] In an early paper in this journal, Feeny and Ives [24] develop qualitative guidelines to help senior executives assess the long term value of IT investments, and mention the importance of considering competitive responses.

[2] Variants of the Red Queen Theory also appear in the biology [68] and economics [53] literature in that they follow this 'observe competitive environment and then respond' paradigm in an evolutionary process.

http://dx.doi.org/10.1016/j.im.2014.05.005
0378-7206/

The Red Queen's response is that Alice must be from a slow world because in a fast world, one must run just to stay still.

To see the consequence of response delays on business performance more clearly, consider a market in which two firms A and B each sell a similar compact car. They each have a 50% market share at time $T = 0$. Let us say that at $T = 10$, A unveils a new engine with double the fuel efficiency of the old engine. If we make the unrealistic assumption that B can instantly perceive and react to A's move, B will immediately introduce a similarly efficient car and both A and B will continue to enjoy a 50% market share. However, imagine that B takes three time periods to perceive what A did and another five periods to improve its own engine in reaction to A's moves. During these eight periods, A will drain off market share from B, and even if B manages to equal A in terms of fuel efficiency, it will not win back the lost market share. Thus, the equilibrium outcomes for A and Bare very different when perception and reaction delays are considered. What if B improves its engine to be better than A's engine? A must first perceive this difference and then react to it. Again, both steps will involve delays, during which B may recover some market share. Now assume that instead of taking five periods, B can react to A's move in three periods. Could B then beat A over the long run despite not having been the first mover? Even if B cannot beat A but can minimize its loss in market share by reacting quickly, what then is the business value of being able to react faster? Would A and B run faster and faster simply to stay in the same place, as the Red Queen said to Alice? Deducing the dynamics of competitive outcomes quickly becomes complicated when one considers that perception and reaction are phenomena that involve substantial delays.

Given the significance of delays in competitive responses, it is not surprising that organizations have made substantial investments in IT to help reduce these delays and make themselves more agile [41,47]. The focus of this paper is on presenting an approach to quantifying the business value of IT investments targeted at improving organizational speed. In doing so, it also addresses two issues that have not been studied extensively in the literature on IT business value: (a) the presence of significant transient patterns and thus, the need to understand both the timing and the total magnitude of their benefits; and (b) the impact of *ongoing* moves and countermoves by competitors on the realization of IT value. The relationship between digital systems and business value is complex and multifaceted. This study helps to reveal one aspect of that relationship that stems from the non-instantaneous nature of competitive responses. At this point, it would also be worthwhile to pause and recognize additional important facets of IT business value such as governance and alignment [6,7,55]. To consider all of these multiple facets, standardized best-practice frameworks have evolved to combine them in a systematic and comprehensive manner when evaluating a specific IT investment opportunity. Examples of such frameworks include COBIT, of which Val IT is a part, and ITIL [16,33,69].

The remainder of the paper is structured as follows. Section 2 reviews the IS (information systems) literature on the business value of digital systems under conditions of competition, the competitive dynamics literature on response delay, and the impact of digital systems on perception and reaction delays. Section 3 presents our system dynamics model of competition. Section 4 presents the experimental results and Section 5 discusses their implications.

2. Literature survey

2.1. The business value of digital systems under competition

There is extensive literature, albeit with mixed findings, on the impact of IT investments on firm performance. A variety of theoretical and empirical studies have analyzed IT value at different levels of aggregation. A comprehensive review and conceptual classification of this body of work from the recent past may be found in Melville et al. [45]. However, although this literature is substantial, only a relatively small proportion of it explicitly considers the impact of continuing competitors' actions on the temporal pattern and magnitude of value realized from IT investments. For the purposes of this paper, we limit our review to a sample of studies from this segment to identify methodologies and common assumptions. Demirhan et al. [21] investigate IT investment decisions in a competitive market under declining costs. They develop a sequential duopoly model and find that declining IT costs intensify or relax competition, depending on whether firms serve quality- or price-sensitive markets. Thatcher and Pingry [67] develop a series of two-stage duopoly models of quality-price competition and a series of monopoly models of quality-price choice to examine the impact of IT investments on firm profit, firm productivity, and consumer welfare. Quan et al. [50] propose a duopoly model to study the impact of investments in digital systems on firm performance and productivity under competitive conditions. They show that the magnitude of benefits is a function of market sensitivities to the price and quality of the products and services offered by a firm and its competitor. Interestingly, Loukis et al. [40], using firm-level data from Greek companies, find that external competitive conditions induce companies to utilize their IT investments more effectively, resulting in the realization of higher business value from these investments. Tan et al. [65] investigate the word-processing-software marketing war in South Korea using a game-theory approach and suggest several reasons why the new entrant was able to overtake the native incumbent and become the market leader. Although the previous articles primarily consider two-party games, researchers outside the IS area have developed methods for efficiently representing multi party-games and algorithms to find equilibrium solutions in special cases such as single-stage tree-structured games [35].

The strength of these studies is that they explicitly consider the actions of competitors in determining the business value of digital systems, which is appropriate given contemporary business environments. At the same time, modeling techniques assume that key competitor actions and market events are instantaneous when in reality, they are not. For instance, in a two-period game, participants are usually assumed to make their moves instantly at the beginning or end of a period. Similarly, customers are assumed to perceive a price/quality change instantly, again at the beginning or end of a period. This assumption of instantaneous behavior is perfectly appropriate when actions/decisions take a short amount of time relative to the overall duration of a game and when the emphasis is on analyzing equilibrium or steady-state outcomes [27]. However, although equilibrium analysis is important and very informative, it is also evident that a game-theory approach would have limited ability to explicitly model delays in competitive responses or deduce the nature of the transient behavior that precedes equilibrium. Accordingly, a game-theory approach is a less attractive candidate to analyze the business value of IT that aims to reduce competitors' perception and reaction delays and make them more agile.

We conclude this survey by mentioning three articles that represent a class of studies that do not explicitly consider continuing competitor actions but do examine the impact of IT investments on a firm's ability to respond swiftly to changes in its environment. Altschuller et al. [1] examine whether IT investments improve a firm's ability to rapidly sense and respond to its environment by analyzing firm performance during periods of industry turbulence. Although specific competitor actions are not explicitly considered, those authors do find that IT investments improve firm agility only in industries with unanticipated growth. Zain et al. [76] use structural-equation modeling to analyze the relationship between technology acceptance and organizational agility by surveying 329 managers of Malaysian firms. Again, specific competitor actions are not considered in the analysis, agility is assessed based on managerial perceptions, and the technology-acceptance model is used to assess organizational assimilation of technology. Roberts and Grover [52] examine a specific form of organizational agility—i.e., that of being able to respond quickly to customer-based opportunities for innovation and competitive action. They use a two-stage research design in which 1, 200 marketing executives were sent surveys, resulting in 188 usable responses. They find that Web-based customer infrastructure improves a firm's customer-sensing capability, whereas internal systems integration improves a firm's customer-response capability. Although these studies do not explicitly capture the mechanics by which IT investments improve an organization's agility, and therefore the impact on response delays, their value lies in identifying attributes of an organization's IT infrastructure that are positively associated with agility. In doing so, they help us to gain a better understanding of the underlying mechanics of agility, which in turn enables us to make IT investment decisions more confidently.

2.2. Response delays in competitive dynamics

Despite its impact on performance, competitive response delay has not received much attention in the IS literature; however, it has been a key issue in the strategy literature. The theories developed by the strategy literature provide a foundation on which to model the dynamics of IT business value under competitive response delays. This literature holds that firms profit by taking competitive actions that maximize rivals' response delays [13] and by responding quickly to rivals' actions [60]. The basic premise is that the longer an initiating firm can monopolize a market and enjoy first-mover advantages based on a new competitive action, the greater the benefits [37,48]. Responding to a rival's action first requires awareness of that action and then the ability to react [14]. If a firm is not aware of a rival's action, it cannot respond, and the response delay will be longer. Likewise, if a firm does not possess the capability to react to a rival's action, it cannot respond until it develops the capability to do so, and the response delay will be longer. Thus, we can decompose response delay into two main components: perception delay and reaction delay.

Chen [14] suggests that awareness is a prerequisite of any competitive move, and that competitors tend to be highly aware of rivals' actions in conditions of high market commonality and resource similarity. Awareness can be facilitated by scanning, in which firms passively or actively view their environments while they collect environmental data and analyze them for relevant signals about future threats and opportunities [19]. Examples include detecting shifting preferences of buyers, changes in supplier industries, changes in availability of complementary products and services, and changes in competitor profiles. Scanning also enables early detection of signals about changes in competitors' capabilities and impending actions, facilitates analysis of the impact of competitors' actions and thus, enables the formulation of appropriate responses [75]. Continuous and real-time scanning of competitive data using digital systems reduces the time taken from a competitor's initiation of an action to perception and interpretation of its effects by the focal firm, thereby reducing perception delays. Online business intelligence services that screen, categorize and display information about strategic activities and emerging technologies from numerous sources enable organizations to perceive competitor actions more quickly and accurately [42]. More recent tools for gathering competitive intelligence—such as text and web mining, visualization and associated organizational processes [5] and the availability of commercial satellite imagery [26]—can provide invaluable competitive intelligence, thus enhancing the speed and accuracy of perception.

A firm's capability to react to a rival's action also has an impact on response delay. Smith et al. [60] show that the type (strategic versus tactical) and radicality (deviation from industry norms) of an initiating firm's action affect the extent of its rivals' response delays. Whereas tactical actions such as price cuts may be easily imitated, strategic actions such as new product introductions are difficult to imitate, leading to considerable response delay. Several studies find that competitive actions that require more effort to execute lead to longer response delays [13,60]. As with perception, digital systems can help to significantly reduce reaction delays. ERP packages are a classic example of systems that improve reaction delay because they help coordinate many functions, including order management, materials planning, warehouse management, payables, receivables, and general ledger. Other digital systems that automate manufacturing processes, improve internal coordination, help with decision support and organizational knowledge management and speed up product design also significantly reduce reaction delay [34,57,72]. In short, there are a wide variety of digital systems that can enable an organization to react more nimbly to its competitors.

3. Model development

Different methodologies have been used to study the dynamic behavior of competing entities to suit the objectives of their respective studies [2,4,10,12,22,30,64,70,73]. Our objective is to represent the impact of IT investments on organizational response delays and then to link that impact to organizational performance—specifically, organizational performance in the presence of continuing countermoves by competitors. The Red Queen theory discussed earlier provided a basis on which to structure the model, which we choose to represent using the system dynamics (SD) methodology. The basis of the method is the recognition that the structure of any system—the many circular, interlocking, and sometimes time-delayed relationships among its components—is often just as important in determining its behavior as the individual components themselves. This is precisely contemplated in our scenario of competition between two entities in which competitive responses are not instantaneous and the action-reaction cycle repeats over time. In the SD model, individual cause–effect relationships are synthesized into a holistic causal model of the mechanics underlying a time dependent phenomenon of interest. The method has been used in a wide variety of application domains [17,51], particularly to examine how complex systems behave over time. The basic elements of SD models are feedback, accumulation of flows into stocks and time delays. These elements can be written as a set of differential equations, which are then simulated to deduce system behavior over time [51]. Although individual causal relationships are relatively easier to understand, studies show that humans have considerable difficulty in deducing the collective effects of multiple interrelated causal relationships [39]. The value added by an SD model is that the collective effects of multiple causal relationships can be deduced computationally through simulation, thereby improving our understanding of the dynamic phenomenon in question. Our choice of methodology is therefore motivated by the observation that, based on the Red Queen paradigm, if one can formally represent the *mechanisms* by which perception and reaction delays affect business outcomes, one can computationally deduce the business value of the digital systems that reduce those delays. On the prescriptive front, one can simulate the underlying mechanics under different business scenarios to help make IT investments judiciously. On the descriptive front, observed competitive outcomes can be explained in terms of underlying mechanics and established findings such as the first-mover advantage can be re examined in light of nonzero delays. The basic constructs and terminology of SD are introduced contemporaneously with the model. The reader can find further technical details of the methodology in the earlier references [51]. In the SD methodology, a problem or a system (e.g., ecosystem, political system or mechanical system) is first represented as a causal-loop diagram. A causal-loop diagram is a simple map of a system with all of its constituent components and their cause-effect interactions. By capturing interactions and consequently the feedback loops, a causal loop diagram reveals the structure of a system. By understanding the structure of a system, it becomes possible to ascertain a system's behavior over a certain period. Causal-loop diagrams aid in visualizing a system's structure and behavior, and analyzing the system qualitatively. To perform a more detailed quantitative analysis, a causal-loop diagram is transformed to a stock and flow diagram. A stock is the term for any entity that accumulates or depletes over time. A flow is the rate of change in a stock. A stock-and-flow model helps in studying and analyzing the system in a quantitative way and is built and simulated using computer software. Due to space limitations, we represent our problem directly as a stock flow model. The repeated action-reaction cycles implied in the Red Queen paradigm naturally lead to a complex web of feedback loops, and the SD methodology is particularly well suited to representing feedback structure.

We modeled the simplest competitive scenario in which the market consists of two firms and customers who choose between their offerings. To ground our narrative, let us assume that the two firms are mobile telephone service providers F (firm) and C (competitor). Following the Red Queen paradigm, they perceive each other's actions and react to those observations, but both perception and reaction take time. For instance, if C becomes aware that F is erecting cell phone towers in a geographic area, then it can conclude that F is in the process of improving its coverage. C can then decide to react, but that reaction will involve some delay. Customers buy services from either F or C depending on the perceived difference in the attractiveness of their offerings. Thus, both firms repeatedly undergo perception-reaction cycles over time, as conceptualized in the Red Queen paradigm [22]. Fig. 1 represents our SD model of the duopoly described above. In SD parlance, that figure is referred to as a Stock Flow Diagram (SFD). An arrow represents a causal relationship from a cause to an effect variable and is called a link. Each link has a polarity. A positive polarity means that cause and effect change in the same direction, whereas a negative link means that cause and effect change in opposite directions.

For ease of identification in the narrative, model variables are written in italics. Many different metrics can be used to measure the business value of an IT investment. Well-established frameworks such as CoBIT, Val IT and ITIL [20,33,69] provide detailed guidance, based on best practices, on how to develop such metrics for industry- and organization-specific contexts. No specific metric is endorsed for all cases, but the importance of having a metric is emphasized. To develop our model, we used market share as the metric to measure business value, represented by the variable *Fshare*. We found this metric attractive, compared to other possible metrics such as revenue or profit, because it captures in a simple and parsimonious way the impact of competitive response delays, which was the focus of our model. Accordingly, we needed a metric that would capture the series of retaliatory moves by both parties, and *Fshare* does that quite well. If one firm's actions confer an advantage relative to the competitor, its market share will increase, and vice versa. There are two main substructures in Fig. 1. The substructure to the right of *Fshare* represents the mechanics of perception and reaction between the two rivals F and C. The substructure to the left of *Fshare* represents the mechanics of customers reacting to the competition between F and C via the perceived difference in the attractiveness of their offerings. Note that <*Adiff*> in the left substructure is the same as *Adiff* in the right substructure. This variable copy avoids cluttering the diagram with a long link from one end to the other. We now discuss each substructure in turn, with links justified by existing theory or other appropriate evidence.

In the right substructure, the competition between F and C is represented at a level of aggregation that keeps the model parsimonious while capturing the major impacts of perception and reaction delays. Strategy theory holds that firms deploy their capabilities in various configurations to bring their products and services to the market place [3,43,48,66]. Capabilities include both tangible and intangible resources, along with associated processes and structures that enable the coordination and execution of organizational activities. In our mobile telephony example, the capabilities of F and C would include the engineers, managers, sales representatives, backbone networks, transmission towers, mobile handsets, and associated business processes. The capabilities of F and C are represented by the stock variables *Fcap* and *Ccap, respectively*. These capabilities result in their respective market offerings that, in our example, would consist of mobile telephony services. These services have multiple dimensions including price, geographic coverage, call quality, customer service and billing accuracy. F's price may be lower but its geographic coverage may not be as comprehensive as that of C. The marketing literature establishes that customers holistically evaluate the multiple dimensions of an offering to form an aggregate assessment of attractiveness, which then forms the basis for comparison among different offerings [8,28,29]. Attractiveness is denoted by *Fattr* and *Cattr* for F and C, respectively. The positive link between *Fcap* to *Fattr* follows from the fact that higher capability leads to more attractive offerings. The relationship is thus monotonically increasing but with decreasing marginal returns and is well-established in the literature [54].

The literature on organizational capabilities suggests that there are limits to capability development and potential for diminishing returns. Helfat and Peteraf [31] propose a model of capability life cycles that begins with a founding stage in which capabilities begin to form, followed by a development stage in which capability building occurs, followed by a maturity stage in which capability building ceases and capabilities reach maturity. Research on capabilities further suggests that capability development exhibits a pattern of diminishing marginal returns. For instance, Slotegraaf et al. [59] show that returns to market deployment of brand equity and R&D activity monotonically increase but exhibit a pattern of diminishing marginal returns. Chu and Keh [15] examine the effects of lagged advertising, marketing promotions and R&D expenses on brand value and show that these lagged expenses result in diminishing returns. Fortin and Dholakia [25] show that there are diminishing returns from the use of the more complex interactive web-based advertising. Similar behavior has been observed in studies of other sectors, such as banking [49]. Finally, Slotegraaf and Dickson [58] suggest that returns from high levels of capabilities exhibit diminishing marginal returns due to the potential competency traps associated with such highly developed capabilities. Thus, based both on the foregoing observations and on the fact that attractiveness of product offerings reflects organizational resources and capabilities, we employed a commonly used and simple negative exponential based function to represent this relationship as $Fattr = a_1 * (1 - \exp(-a_2 * Fcap))$. A similar expression related *Ccap* to *Cattr*. The difference in attractiveness, given by $Adiff = Fattr - Cattr$, drives customer-switching behavior, the mechanics of which are discussed shortly; for now, however, we continue with the mechanics of the competition between F and C.

The strategy literature shows that a firm perceives a competitor by observing both its capability and its offerings [18,61]. As noted above, perception involves delay, and digital systems have been used by organizations to improve the quality of and delay associated with perception [11,36]. Investment in digital systems that expedite perception was represented by *CDS1* and *FDS1* for C and F, respectively, in Fig. 1. C's perception delay was represented by *PdelayC*, the functional form being $PdelayC = a_3 * \exp(-a_4 * CDS1)$. A similar expression for F's perception delay is shown in Table 1. The negative exponential form captured diminishing returns to scale typically exhibited by investments in technology [38].

Following conceptual developments in the strategy literature mentioned in the preceding paragraph, C's perception of F's capability was represented by *CpFcap* and in line with the foregoing discussion, had inbound links from *Fcap*, *Fattr* and *PdelayC*. The functional form was given by $CpFcap = \text{Delay}(a_5 * Fcap + (1 - a_5) * Fattr, PdelayC) + PerrorC$, where $PerrorC = \text{RANDOM UNIFORM } [-a_6, +a_6]$. Following our earlier observation that perceptions of capability result from observing the competitor's capability and offerings, the input to the delay function was the weighted average $a_5 * Fcap + (1 - a_5) * Fattr$. This input was delayed by *PdelayC* to yield the perceived capability *CpFcap*. An error term, *PerrorC*, was later added because, as noted earlier, perception was also imperfect. *PerrorC* was assumed to be uniformly distributed between an upper and lower limit, with the range depending on the level of investment in digital systems for perception, the functional form being $a_6 = a_7 * e^{CDS1}$ to represent diminishing returns to scale. With additional investment in digital systems to improve perception, not only does the perception process become faster but also it becomes less susceptible to error. Thus, the range of the uniform distribution representing error in perceptions shrinks as *CDS1* increases. There was a similar link structure leading into *FpCcap* (F's perception of C's capability). The double hash mark on selected links indicates a delayed cause–effect relationship.

Table 1
Functional forms of model variables with annotations.

Eq. No	Functional relationships
1	$\text{Fattr} = a_1 * (1 - e^{-a_2 * \text{Fcap}})$, $\text{Cattr} = a_1 * (1 - e^{-a_2 * \text{Ccap}})$ Experiment Value: $a_1 = a_2 = 1$ Fattr(Cattr) increases monotonically with Fcap(Ccap), but at a decreasing rate, due to well established phenomenon of diminishing returns to scale
2	$\text{Adiff} = \text{Fattr} - \text{Cattr}$ Difference in attractiveness of the offerings of firms F and C
3	$\text{PdelayC} = a_3 * e^{-a_4 * \text{CDS1}}$, $\text{PdelayF} = a_3 * e^{-a_4 * \text{FDS1}}$ Perception delay of C(F) decreases monotonically with increasing investment in digital systems for perception CDS1(FDS1). The negative exponential captures decreasing returns to scale that is characteristic of technology investments. Experiment value: $a_4 = 1$, $a_3 = 20$ periods
4	$\text{CpFcap} = \text{Delay}\ (a_5 * \text{Fcap} + (1 - a_5) * \text{Fattr, PdelayC}) + \text{PerrorC}$ C's perception of F is a weighted average of F's capability and F's attractiveness after some delay. The weights are a_5 and $(1 - a_5)$. The amount of delay is PdelayC. Additionally, perception is not perfect and is subject to error. This is captured by the error term PerrorC. $\text{FpCcap} = \text{Delay}\ (a_5 * \text{Ccap} + (1 - a_5) * \text{Cattr, PdelayF}) + \text{PerrorF}$ F's perception of C. Same logic as that for CpFcap $\text{PerrorC, PerrorF} = \text{RANDOM UNIFORM}\ [-a_6, +a_6]$ Perception error by C(F). Drawn from a uniform random distribution. $a_6 = a_7 * \mathrm{e}^{-\text{CDS1}}$; $a_6 = a_7 * \mathrm{e}^{-\text{FDS1}}$; A higher investment in digital systems by either C or F not only reduces perception delay but also reduces perception error. Thus the range of the uniform random function $[-a6, +a6]$ shrinks. This reduction in range is captured by the negative exponential function. Experiment value: $a_7 = 1$

5	IF (FShare > 0.5 OR Trend(Fshare) > 0) THEN max(0, CpFcap-Ccap) ELSE 0
	If C has a lower market share than F, or if F is gaining in market share, then C responds by increasing its own capabilities.
	IF (FShare < 0.5 OR Trend(Fshare) < 0) THEN max(0, FpFcap-Fcap) ELSE 0
	If F has a lower market share than C, or if C is gaining in market share, then F responds by increasing its own capabilities.

6	$\text{RdelayC} = a_3 * e^{-a_4 * \text{CDS2}}$, $\text{RdelayF} = a_3 * e^{-a_4 * \text{FDS2}}$ Reaction delay of C(R). Same reasoning for functional form as in Eq. (3) for perception delay
7	DelCcap = Delay(DesiredDelCcap, RdelayC) DelFcap = Delay(DesiredDelFcap, RdelayF) Increment in capability of C(orF) occurs only after a reaction delay. Magnitude of delay is given by RdelayC (RdelayF)
8	$\text{AdiffSensi} = a_8 * \text{Tanh}(a_9 * \text{Adiff})$ S-shaped function that captures customers' sensitivity to difference in attractiveness of F and C. Experiment value: $a_8 = 1$, $a_9 = 5$.
9	Fshare = Fcust/(Fcust + Ccust)

In our model, C perceived F's capability, *CpFcap*, and its own position relative to F in market share $(1 - Fshare)$. Its reaction was to want to increase its own capability by a certain amount given by *DesiredDelCcap*, the functional form being given by $DesiredDelCcap = \text{IF} \ (FShare > 0.5 \ \text{OR} \ \text{Trend}(Fshare) > 0) \ \text{THEN} \ \max(0, CpFcap - Ccap) \ \text{ELSE} \ 0$. This expression caused C to react if either its market share was less than that of F ($Fshare > 0.5$) or if F was gaining on C ($\text{Trend}(Fshare) > 0$). The magnitude of the desired increase is the difference between C's perception of F's capability and its own. A similar equation specified the logic of F's reaction and can be found in Table 1. *DesiredDelCcap* results in actual change in C's capability, *DelCcap*, but only after a delay, *RdelayC*, because a firm cannot react instantaneously. For instance, when MCI introduced its Friends and Family program sometime around1990, it took some time for AT&T to reengineer its billing routines and business process to respond to this move, and MCI drew customers away from AT&T in the interim. As with perception, digital systems are commonly used by organizations to reduce reaction delay [74]. For instance, organizations often implement ERP systems to improve business process integration and their ability to respond more nimbly to changing business environments. Research indicates that these implementations take substantial amounts of time depending on a variety of factors [56]. A more extensive example of investing in IT to achieve operational agility can be found in a case study of the Haier company [32]. Investment in digital systems for reduction in reaction delays was represented by *CDS2* for C and*FDS2* for F. Based on the same logic presented earlier for *PdelayC*, the reaction delay for C was given $RdelayC = a_3 * e^{-CDS2}$. Actual increase in C's capability was therefore given by $DelCcap = \text{Delay}(DesiredDelCcap, RdelayC)$. A similar set of equations governed F's reactions, as shown in Table 1.

Now that individual links in the right substructure of Fig. 1 have been presented and justified, we can identify the macro causal mechanisms resulting from the synthesis of individual links. Consider the feedback loop: $Fcap \rightarrow^{+} CpFcap \rightarrow^{+} DesiredDelCcap \rightarrow^{+} DelCcap \rightarrow^{+} Ccap \rightarrow^{+} FpCcap \rightarrow^{+} DesiredDelFcap \rightarrow^{+} DelFcap \rightarrow^{+} F\text{-}Fcap$. *Multiplication of the link polarities (shown alongside each arrow) results in a positive polarity, indicating that this is a positive feedback loop. The physical interpretation of this loop is one of escalation where, if F increases its capability, C's perception of F's capability will increase, leading to C increasing its own capabilities. This move will cause F's perception of C's capability to increase, leading F to further increase its capability because of the responses made by C. This type of escalation is seen in the FedEx vs. UPS example presented earlier. Now consider the feedback loop:* $Fcap \rightarrow^{+} Fattr \rightarrow^{+} Adiff \rightarrow^{+} AdiffSensi \rightarrow^{-} Fcustout \rightarrow$

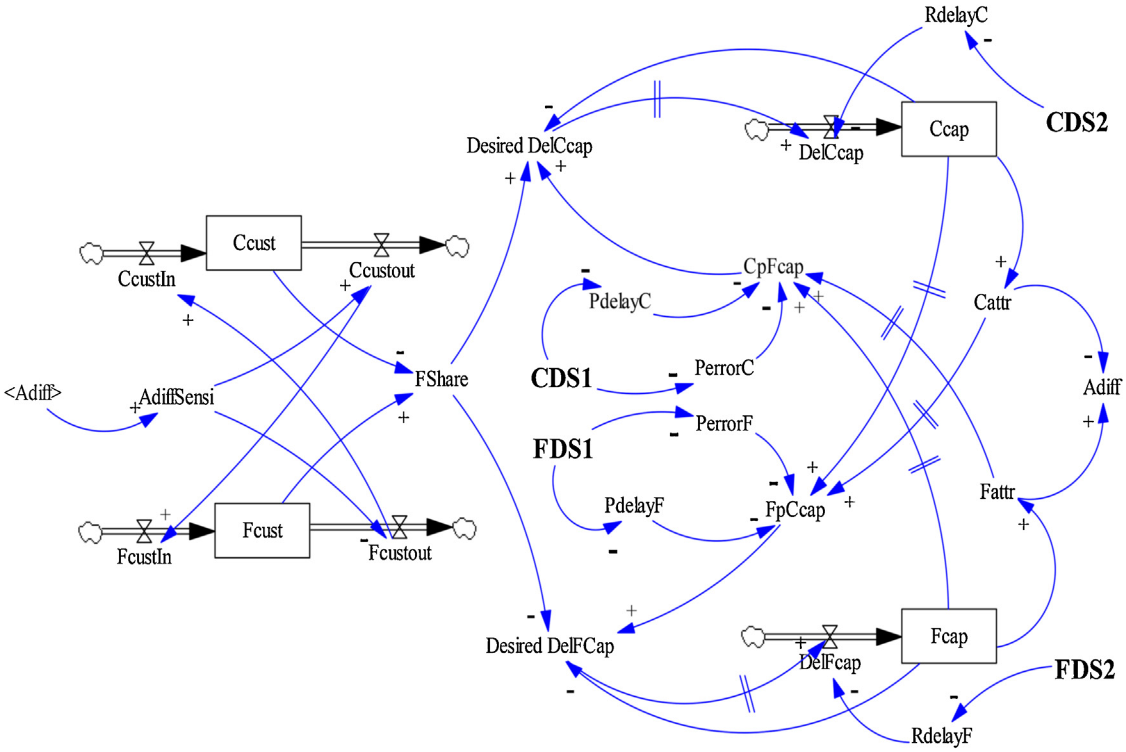

Fig. 1. Impact of perception and reaction delays on competitive outcome: stock flow diagram.

$^{-}$ *Fcust* $\rightarrow^{+}$ *Fshare* $\rightarrow^{-}$ *DesiredDelFcap* $\rightarrow^{+}$ *DelFcap* $\rightarrow^{+}$ *Fcap. Multiplying the individual link polarities results in a negative polarity, showing that this is a negative feedback loop. This loop indicates that in the absence of a reaction from C, an increase in Fcap results in an increase in the attractiveness of its offering Fattr, which in turn leads to fewer customers leaving (Fcustout), leading to an increase in its market share Fshare. This in turn reduces the need for F to increase its capability, which throttles back the original increase in Fcap. Of course, the two loops interact both with each other and with others shown in Fig. 1. The collective impact of these feedback loops produces the competitive dynamics between F and C.*

The substructure in Fig. 1 lying to the left of *Fshare* represents the mechanics of customers switching between F and C based on the difference in attractiveness of offerings, *Adiff* = *Fattr* − *Cattr*. *AdiffSensi* was the proportional change in the rate at which C's customers switch over to F as a function of *Adiff* for positive values of *Adiff*. For negative values of *Adiff*, *AdiffSensi* regulates customer switching from F to C. The greater the difference in attractiveness between F and C, the higher the rate at which customers switch from one to the other. However, there is also a saturation effect in that defection of customers between F and C plateaus out for large values of *Adiff* [25,46]. Thus the graph of the customer switching rate *Adiffsensi*, as a function of the difference in attractiveness *Adiff*, exhibits an S-shape that goes through the origin (0,0). We used the functional form *AdiffSensi* = a_8 * Tanh(a_9 * *Adiff*) because the hyperbolic tangent function is a compact and common way of capturing such an S-shaped behavior. *AdiffSensi* had links to *Ccustout* and *Fcustout*, controlling the flow of customers switching away from C or to F. F's market share was computed as *Fshare* = *Fcust*/(*Fcust* + *Ccust*).

The overall causal structure of Fig. 1 reflects the well-established perceive-react paradigm of competition referenced earlier and explicitly represents the impact of nonzero delays in perception and reaction. *CDS1*, *FDS1*, *CDS2*, *FDS2*, represented investments in IT that help reduce perception and reaction delays. The causal model of Fig. 1 links these investments to the transient behavior and equilibrium values for *Fshare*, thus providing a measure of the business value resulting from these investments and revealing the mechanics by which this value creation occurs.

4. Experimental results

The stock-flow model shown in Fig. 1, populated with the functional forms discussed in the preceding section, was implemented using Vensim® SD software [71]. The aim of these experiments is to determine not only the equilibrium and transient behavior of *Fshare* but also the underlying mechanics causing them. The experiments also illustrate our approach to quantifying the business value of digital systems used for competitive responsiveness and making a business case for them. We also draw managerial implications about the business value of IT that firms can expect to realize under competitive conditions.

4.1. Baseline parameters and initial values

The values of key variables were normalized to lie between zero and one, with each anchor point having an appropriate interpretation. Normalization facilitated a comparison of policy outcomes and enabled us to see general patterns of behavior that are not influenced by absolute values associated with specific circumstances. Provided the end points of the normalization have clear interpretations, the simulation results generated by the normalized values can also be given a clear physical interpretation. Thus *Fcust* = 1 means that F has all the customers in the market. *Ccap* = 1 represents an ideal best configuration of capabilities for C whereas *Ccap* = 0 represents an absence of capabilities. A conceptual continuum of capability was assumed between these two anchor points. Thus, in our experiments, both competing firms could, in principle, reach the same ideal best capability given a sufficiently long time period. Of course, at any one point in time, they may have vastly different capabilities. Similarly, *Fattr* and *Cattr* range between 0 and 1. They represent anchor points on a conceptual continuum of attractiveness, with 1 representing an ideal point. The concept of 'ideal points' in the evaluation of products by customers is well established in the marketing literature [23]. *CDS1*, *CDS2*, *FDS1* and *FDS2*, likewise, range between 0 and 1, with 1 representing the highest investment that could reasonably be contemplated by either competitor. As a consequence of normalizing key variables to lie between zero and one, many of the coefficients of the functional relationships between cause and effect also must be set to one. These values are shown in Table 1. Because many digital systems simultaneously help reduce perception and reaction delays,[3] for simplicity we set *CDS1* = *CDS2* and *FDS1* = *FDS2* in the simulation runs, and represented them by *CDS* and *FDS*.

F and C were set to be identical in their initial capabilities and each had the same initial number of customers. Customers were assumed moderately sensitive to differences in attractiveness of the competing offerings. Although competing firms often do not start out as identical, we deliberately made them identical in the experiments. Otherwise, when there were changes in transient behavior or equilibrium outcomes, it would have been difficult to isolate the impact of initial conditions from that of perception/reaction delays, compromising the objective of our study. Thus the initial values are *Fcust* = 0.5, *Fcap* = *Ccap* = 0.2, *CDS* = *FDS* = 0.1, *AdiffSensi* = 0.5. If the baseline scenario persists and neither participant makes a move, equilibrium holds and F and C each continue to enjoy a 50% market share indefinitely.

4.2. Dynamic behavior of competitive outcome

In the first set of experiments, F makes a first move by introducing a step increase in its capability at *T* = 10. The dynamic behavior of competitive outcomes, represented by *Fshare*, is then examined for different combinations of investment in IT by the two competitors.

Case#1-Baseline(CDS = Low, FDS = Low): Here, both C and F have low levels of investment in digital systems for perception and reaction (CDS = FDS = 0.1). Fig. 2 shows the resulting behavior of *Fshare* and that of *Fcap*, *Ccap*, *FpCcap* and *CpFcap* (F's capability, C's capability, F's perception of C's capability and C's perception of F's capability, respectively).

Fig. 2 shows the short-lived nature of the first-mover advantage, not unlike the FedEx-UPS rivalry. *Fshare* (Line#1) starts at 0.5, the equilibrium condition, and increases rapidly when F increases *Fcap* at *T* = 10 (Line#4). This is because F has suddenly increased its capability, resulting in its offering being more attractive than that of C and more customers switching over to F. C's perception of F's change in capability is neither instantaneous nor perfect—notice the random variations in *CpFcap* (Line#3) and that it starts to rise only several periods after *T* = 10. The increase in *Fshare* causes C, following Eq. (5) in Table 1, to respond by increasing its own capability. However, reaction takes time, resulting in *Ccap* (Line#2) increasing several periods after *T* = 10. During this 'catch up' period, F continues to win at the expense of C, as seen in the increase in *Fshare* until about *T* = 24. Interestingly, although first-mover F has won thus far, its winnings do not last. After *T* = 24, *Fshare* begins to drop, indicating that C has not only stemmed the gains of the first mover but also is actually regaining some of its lost ground. This follows from the second feedback loop identified in Section 3, which causes C to react to F. In fact, at around *T* = 38 *Fshare* dips below 0.5, indicating that C has beaten first-mover F in market share. C continues to beat F in market share until about *T* = 44, at which time F starts to recover. This time, F is playing catch-up, in part due to its own perception and reaction delays. In equilibrium, *Fshare* goes back to approximately 0.5 because over the long run, F and C catch up with one another. Thus, in this scenario, first-mover F's gain in market share was temporary, but it did come out ahead of C in total gains over the duration of the game. This follows from the observation that the area of the *Fshare* curve above the *Fshare* = 0.5 reference line is greater than the area below. Note also that the business value of the capability increase was realized completely during the transient phase. This important insight is revealed because the SD methodology explicitly focused on modeling the delay and transient behavior.

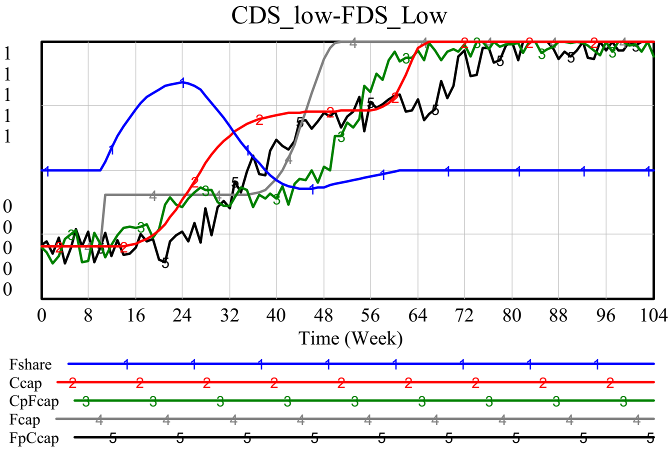

Fig. 2. Dynamics – low DS investment levels.

This 'overshoot' and 'undershoot' in *Fshare* is primarily a consequence of perception and reaction delays. It is well known that delays generate oscillatory behavior in physical and social systems [51]. C responds by aiming to match F's increased capability, but because of C's perception delay it continues to increase capability even after F has stopped increasing its capability. Moreover, *Ccap* continues to increase for a short time because planned increases take time to manifest, due to reaction delays. By overshooting, *Ccap* becomes greater than *Fcap*, which enables C to recapture some lost ground. When C becomes more capable than F, F responds using the same type of mechanics, which explains the rise back to *Fshare* = 0.5 from *T* = 44 onwards.

Case#2 (CDS = Medium, FDS = Medium). In Case#2, both C and F have medium levels of investment in digital systems (CDS = FDS = 0.5). The resulting behavior of *Fshare*, seen in Fig. 3, is similar to that in Fig. 2 because the same mechanics are at work.

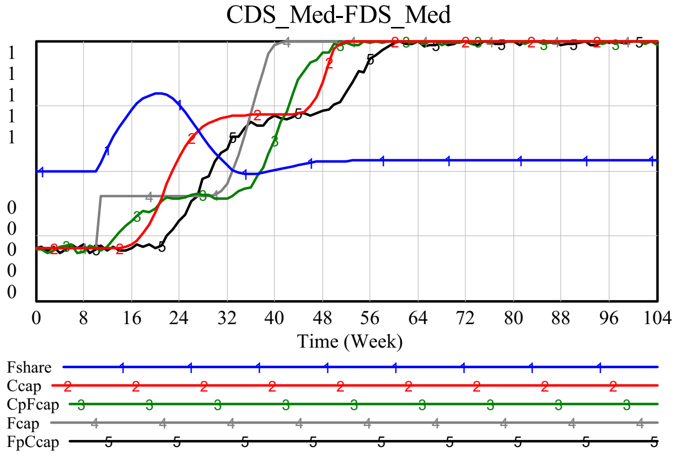

Fig. 3. Dynamics – medium DS investment levels.

---

[3] For instance, a Customer Relationship Management (CRM) system can alert F to actions by competitor C via the feedback or complaints received from customers. The customer behavior and preference data collected by the same CRM may also simultaneously enable F to react to C's moves.

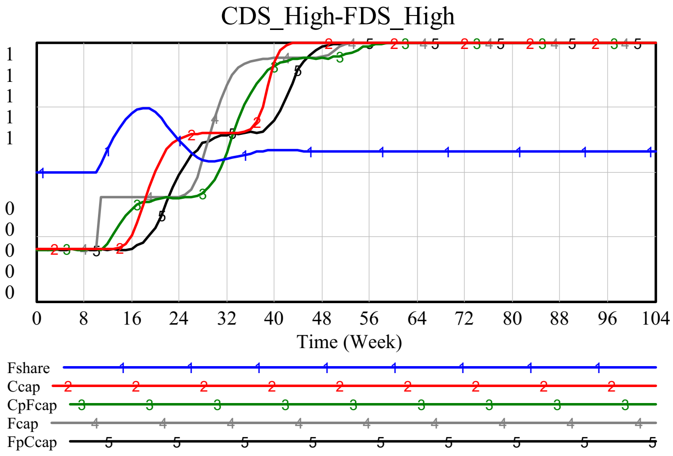

Fig. 4. Dynamics – high DS investment levels.

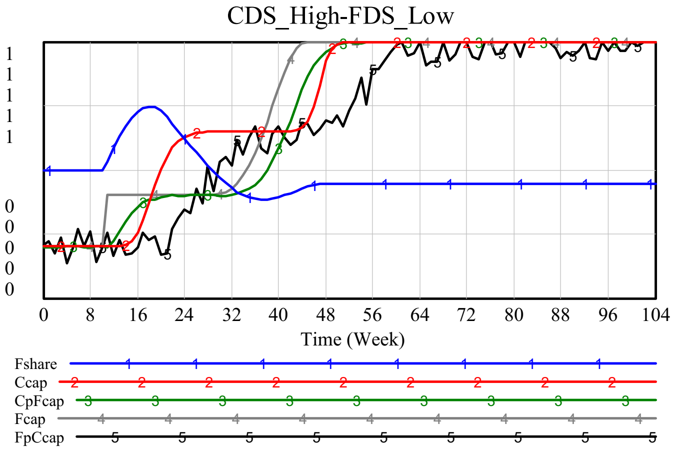

Fig. 5. Dynamics – C_High, F_Low DS investment.

Perception and reaction delays can again be seen in the temporal behavior of *Fcap*, *Ccap*, *FpCcap* because F and C perceive and react to one another. However, in this scenario, F maintains its gain in *Fshare* over the long term, as seen by the equilibrium value of *Fshare* (Line#1) being greater than 0.5. The reason is that C, despite reacting faster than in Case#1, is unable to win back customers who switched over to F during the first move because F is now also reacting faster than it did in Case#1(CDS and FDS are both = 0.5). This behavior suggests that a threshold effect is at work in that first-mover advantage could be sustained if the investment in digital systems by this mover exceeds a particular threshold.

Case #3:(CDS = High, FDS = High). Here, both F and C have high levels of investment in digital systems (CDS = FDS = 0.9). Fig. 4 shows the resulting behavior of *Fshare*. Although the transient patterns of variables in Figs. 2 and 4 are similar, the differences in magnitude are significant and can be related back to investment in digital systems and the resulting impact on delays. First, the equilibrium value of *Fshare* in Fig. 4 is greater than 0.5, meaning that the first mover sustains superiority in market share over the long run under conditions of high investment in digital systems, whereas it did not under low investment levels. Additionally, the peaks and troughs of the transient portion of *Fshare* are smaller in Fig. 4 compared to Fig. 2. This difference can again be understood from the transient patterns of *Fcap*, *Ccap*, *FpCcap*, and *CpFcap* in the two figures. When investment in digital systems is high, both F and C have low perception and reaction delays. Thus, they chase each other more rapidly, as seen by the greater number of capability building cycles in Fig. 4. Neither side can get too far ahead before the other catches up. The reason that F ends up with a long-run advantage is that by the time both competitors reach the ideal best capability of one, F has won more customers away from C than it has lost back to C during the tit-for-tat moves. Once both competitors have reached the ideal best capability, then further improvements in capability do not occur for either party. This stagnation in capability at the ideal best level is an artifact of our model, of course, and its proper interpretation in real-life situations is discussed in the concluding section.

Case#4: (CDS = High, FDS = Low). Here, we used asymmetric levels of investments in digital systems by F and C to examine if C can overcome the first-mover advantage of F over the long run simply by being more agile than F. Notice in Fig. 5 that the steady-state value of *Fshare* is less than 0.5, implying that C has indeed been able to beat first-mover F over the long run by being substantially faster in both perception and reaction. Thus, the first-mover advantage of F not only was temporary, reflected by *Fshare* being greater than 0.5 from $T = 10$ to about $T = 28$, but also F was not even able to recover back to its initial market share of 0.5. The transient patterns of *Fcap* and *Ccap* in Fig. 5 reveal that C was quick to respond to F's first move but that F took a much longer time to counter. When it did, C was able to again perceive and react more quickly. By the time both competitors achieved the ideal best capability of one, C had won back all of the customers that F had drained away with its first move. Additionally, C continued to take customers away from F and F reached its capability limit before it could recapture that loss. Thus, F's long-run

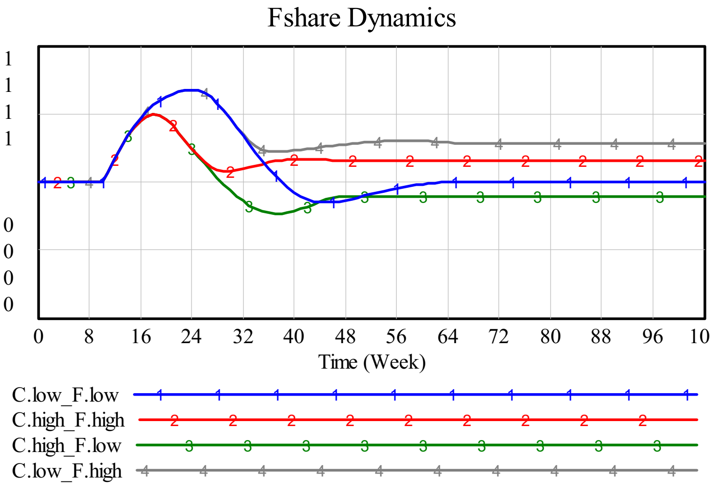

Fig. 6. Fshare behavior for different DS combinations.

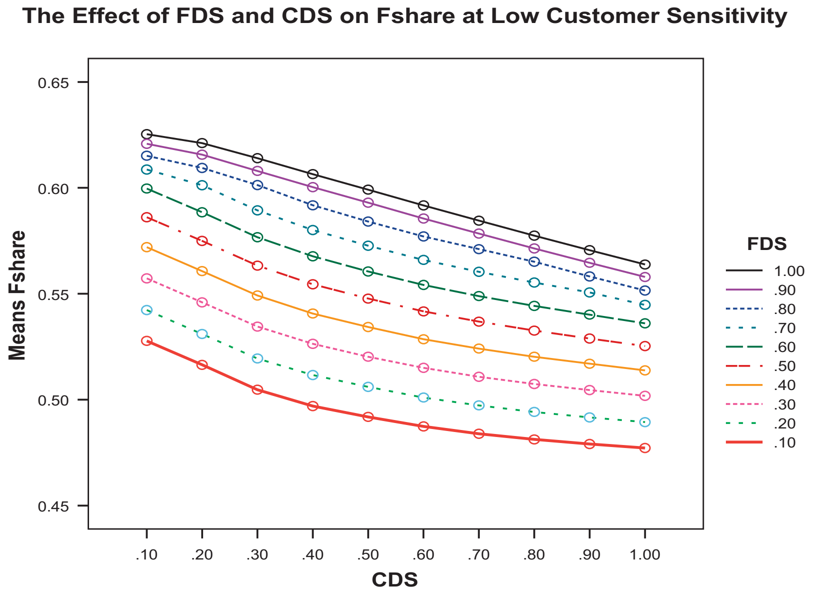

Fig. 7. Effect of FDS and CDS on Fshare – low customer sensitivity.

market share is less than 0.5, despite being the first mover. Therefore, Case#5 indicates that there may be some merit to being a very agile follower rather than a first, but slow, mover.

Fig. 6 compares the dynamic behavior of *Fshare* under different combinations of investment in digital systems. It reveals patterns in both the steady-state value of *Fshare* and its transient behavior. The results show that a competitor may, in the long run, be able to stop or reverse the gains of a first mover by investing more in digital systems to reduce its perception and reaction delays relative to the first mover. We can also see that the magnitude of transient gains or losses in market share experienced by the competitors increases with delay. In other words, higher investment in digital systems can enable C to limit the extent of temporary gain achieved by the first mover.

In many studies of IT value, the emphasis is on equilibrium or long-term outcomes. Our experiments show that it is just as important to understand the transient behavior of business outcomes, for example, *Fshare*, resulting from IT investments. We draw this conclusion because although the model simulates the long-term ($T = 104$) consequence of a first move by F, in reality, the interaction among firms is a sequence of such games, and one game may 'start' before the previous one has reached steady state. Thus, an analysis of business value of an IT investment may need to focus primarily on transient behavior in highly competitive environments.

4.3. Analysis of equilibrium outcomes

We also examined the sensitivity of long-run equilibrium values of *Fshare* to different levels of investments in digital systems and customer sensitivity, as shown in Figs. 7 and 8. FDS, CDS and *AdiffSensi* range from 0.1 to 1.0 in increments of 0.1. For ease of presentation, we created two categories of *AdiffSensi*: low [0.1–0.5] and high [0.6–1.0]. In the former category, customers were less

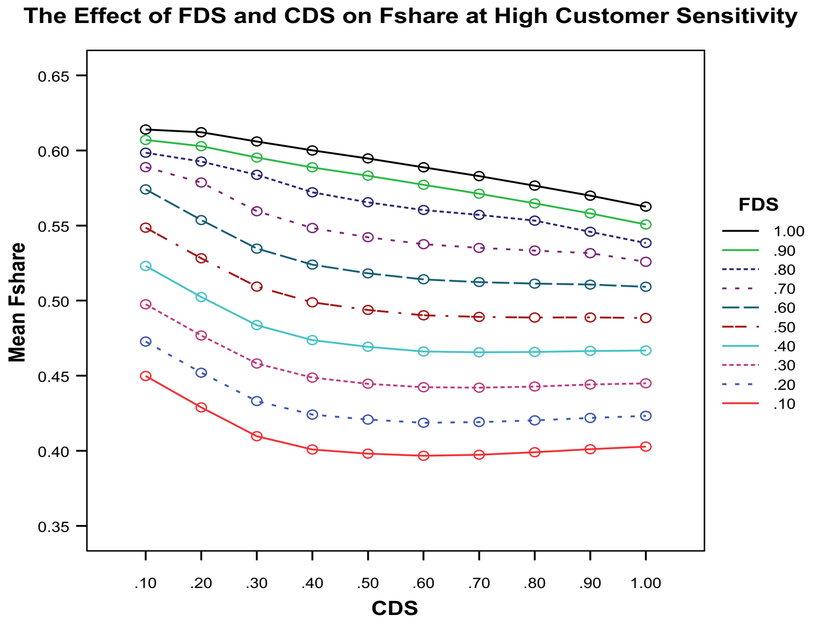

Fig. 8. Effect of FDS and CDS on Fshare – high customer sensitivity.

sensitive to differences in attractiveness of offerings by F and C, while in the latter they were much more sensitive.

Fig. 7 shows that, for low values of customer sensitivity, *Fshare* increases with FDS and this pattern is consistent for each level of CDS. Conversely, *Fshare* declines as CDS increases, and this pattern is consistent for each level of FDS. F retains a first-mover advantage (i.e., $Fshare > 0.5$) when FDS is 0.3 or above, regardless of the level of CDS. However, *Fshare* drops below 50% when $\text{FDS} \leq 0.2$ and $\text{CDS} \geq 0.7$. There is diminishing return for CDS, as seen by the flattening of the slope of *Fshare* when CDS $\geq$ approximately 0.5. There are also diminishing returns for FDS, as seen by the narrowing of the *Fshare* curves between successive values of FDS.

Fig. 8 shows that for high values of customer sensitivity, the general shapes of the *Fshare* curves are similar to those in Fig. 7. However, diminishing returns appears to set in at lower values of CDS and FDS in Fig. 8 compared to Fig. 7. F retains its market share above 50% when $\text{FDS} \geq 0.5$ regardless of the level of CDS. However, *Fshare* drops below 50% when $\text{FDS} \leq 0.5$ and $\text{CDS} \geq 0.4$. These results suggest that for high customer sensitivity, F requires higher levels of investment in digital systems to retain its first-mover advantage.

5. Conclusions and managerial implications

The relationship between IT investment and business value is a complex and multifaceted one and as summarized early in this paper, there is a substantial body of literature on the issue. This study contributes to that literature by focusing on one important aspect of the relationship—that the realization of business value from an IT investment usually occurs in an environment in which competitors perceive and respond to each other's actions and these responses involve delays. Thus, we conceptualize the realization of IT business value as a dynamic phenomenon subject to competitive responses and explicitly model it as such based on the observe-respond Red Queen paradigm. Specifically, when a firm invests in digital systems, the business value of that system will not be accrued instantaneously, but over time, and competitors will not sit still during that time. The strength of our approach is that we modeled the mechanics of this competition, and in particular the response delays, in a much more realistic manner based on existing theories and empirical evidence in the literature. The mechanics of playing catch-up are built into the model. Thus, we can reveal both transient and steady-state patterns of behavior in the business value generated by these digital systems. The current literature on IT business value is predominantly focused on equilibrium or steady-state outcomes. Although this is important, our experiments show that the transient patterns of business outcomes are also significant enough to deserve attention in understanding and assessing the value realized. This understanding and assessment of the dynamics of value need to be integrated with other aspects in conducting a holistic assessment of the value of any specific IT investment, as noted at the beginning of this section.

The Red Queen theory from the strategy literature provided the basic mechanics of competition that formed the foundation of our SD model. We explicitly incorporated response delay into the model and distinguished between its two components—perception and reaction delays. By doing so, we show the effects of digital systems on the speed of a rival's response and the resulting impact on business performance. In keeping with the Red Queen theory, our model incorporated a firm's performance decline (*Fshare*) due to its competitor's actions as a motivator of response. In practice, firms are often compelled to act not only when they realize a decline in performance but also when they see a rival take action. Thus, we added perception of rival's actions as a further response motivator. Because the Red Queen competitive process often occurs over a long period, we also examined the longer-term effects of rivalry [22] and thus deduced the long-term business value contributed by the digital systems. By explicitly recognizing that perception and reaction are not instantaneous events, we were able to examine transient patterns in the realization of IT value in addition to steady-state values compared to the current literature on IT business value, which largely speaks only to steady-state gains.

Our results indicate that investments in digital systems have a positive effect on market share for both the first mover and the competitor. Furthermore, a first mover retains its advantage over the long run provided its investment in digital systems remains above a certain threshold, regardless of the competitor's level of investment in digital systems. However, under the condition of low customer sensitivity, that threshold is also low. Below this threshold, the competitor may dethrone the first mover over the long run provided its investment in digital systems is significantly higher than that of the first mover. In contrast, under the condition of high customer sensitivity, this threshold is substantially higher. Below this threshold, the competitor may dethrone the first mover over the long run provided its investment is close to that of the first mover. Furthermore, both the first mover and competitor experience diminishing returns from their investments in digital systems, particularly when customer sensitivity is high.

In addition to steady state outcome, our experiments show that transient behavior of the first mover's market share is significant in determining the business value of IT investments. In fact, in hyper-competitive environments, one may not achieve a steady state, or the steady state may be very short-lived, in which case the value generated is during the transient phase; current value models do not give us that information. A major benefit of our model is that it could help assess both the magnitude and the timing of business value arising from investments in digital systems. In competitive environments, in which business outcomes are dynamic, it is helpful to understand the realization of business value from digital systems as a function of time. The results indicate that the dynamics of value realization from digital systems is much more volatile in markets where customers are highly sensitive to differences in the relative attractiveness of competitor offerings.

We offer several managerial implications from our research. Most managers emphasize establishing a sustainable competitive advantage and readily recognize the substantial benefits of moving first with competitive actions relative to rivals. However, these same managers often overlook that maintaining a sustained competitive advantage is very difficult in today's hyper-competitive environments and that *first-mover advantages are frequently transient*. In doing so, they tend to rely on past competitive actions and advantages instead of continuously investing in and moving on to the next set of competitive actions and advantages. Our experimental results confirm that *managers should be more conscious of the transient nature of advantages arising from implementing digital systems* before rivals and should attempt to continuously invest and *develop a repertoire of capabilities in digital systems* to stay ahead of rivals. Similarly, many managers often assume that first-mover advantages are instantaneous and minimize the substantial *benefits of responding quickly to a first mover's competitive action*. This perspective coincides with our earlier point on the managerial emphasis of establishing a sustainable competitive advantage by being the first mover. Consequently, managers may abandon imitating the first mover's competitive action and consider moving on to another competitive action. Our experimental results suggest that *perception and reaction delays can be reduced and managers can compete with and even overtake the first mover* by developing similar or better capabilities in digital systems over time. As McGrath [44] recently noted, "*Sustainable competitive advantage is now the exception, not the rule. Transient advantage is the new normal.*" In the competitive dynamics of digital systems, we concur and submit that managers should accept this "new normal" of transient advantage.

Early in this paper, we noted the availability of best practices frameworks, such as ITIL Val IT and COBIT, that outline systematic ways of examining the multiple facets of IT business value in specific instances. Our findings on the dynamics of IT business value can be assimilated into those frameworks at several levels. For instance, Val IT has general guiding principles and more specific processes as part of its governance framework. One example of a guiding principle is that 'IT enabled investments are managed through their full economic life cycle'. Clearly, this guiding principle recognizes that IT business value is not a static phenomenon, but instead is realized over time. Otherwise, there would be no need to manage it over its life cycle. Our findings about the transient nature of first-mover advantage, or the potential advantage of being an agile follower rather than an innovator, are directly relevant to applying this guiding principle. Another guiding principle is 'Value delivery practices recognize that there are different categories of investments that will be evaluated and managed differently'. In other words, all IT investment opportunities are not created equal and must be evaluated differently. Our work highlights the contribution of IT to organizational agility and offers a way to quantify and evaluate that benefit, and thus can inform this guiding principle. When one drops down to processes, Val-IT has several areas for which our findings would be informative. For instance, one of the processes identified under portfolio management is to 'evaluate and select projects to fund'. Our findings can directly inform such a process. Other frameworks such as COBIT and ITIL also describe principles, processes, tasks and checklists with the aim of delivering value from IT investments. Although specifics vary, there is a fair degree of conceptual commonality across these different frameworks and our work can inform the other frameworks in a manner similar to that outlined for Val-IT.

In closing, it is worth observing that the importance of organizational agility, coupled with our ubiquitous dependence on IT, has initiated an examination of agile IT infrastructures in the IS literature [63]. In other words, the literature examines what structures of software, hardware and networking building blocks allow organizations to adapt their IT infrastructure speedily to respond quickly to changes in the competitive environment. As with all models, ours has its simplifications that suggest directions for extensions. Our model assumes homogeneity in customer preferences when in reality, all customers do not have the same preference patterns for quality. This means that coefficients a_8 and a_9 shown in Table 1 need to be changed from constants to probability distributions. Additionally, we could obtain a more refined understanding of competitive dynamics by progressive disaggregation of the attractiveness construct. A first step would be to decompose attractiveness into price and quality. This would allow the model to capture differential reactions to the two dimensions. For example, it could allow a competitor to react immediately to a price move by a rival, but experience a longer delay when reacting to a quality improvement. The modeling of delay can also be customized for specific circumstances. For instance, if the competitive setting is such that when an action is taken, the rival perceives the action gradually, one can use third-order delay functions (in reality, this is the most common occurrence). Conversely, in certain environments, although actions are perceived after some delay, they are perceived all at once instead of gradually. In this situation, one would use infinite order delay functions. One could also conduct additional experiments to explore competitive outcomes under asymmetric initial conditions. In general, the causal model and its implementation using the SD methodology provides a conceptual and computational platform on which to explore competitive dynamics and the impact of digital systems on this phenomenon, thereby providing another framework for assessing the business value of IT investments.

References

[1] S. Altschuller, D. Gelb, T. Henry, IT as a resource for competitive agility: an analysis of firm performance during industry turbulence, J. Int. Technol. Inf. Manag. 19 (January (1)), 2010, pp. 39–40.

[2] S. Bandyopadhyay, J.M. Barron, A.R. Chaturvedi, Competition among sellers in online exchanges, Inf. Syst. Res. 16 (1), 2005, pp. 47–60.

[3] S.L. Berman, J. Down, C.W.L. Hill, Tacit knowledge as a source of competitive advantage in the National Basketball Association, Acad. Manag. J. 45 (1), 2002, pp. 13–31.

[4] G. Bhatt, V. Grover, Types of information technology capabilities and their role in competitive advantage: an empirical study, J. Manag. Inf. Syst. 22 (2), 2005, pp. 253–277.

[5] I. Bose, R. Pal, A. Ye, ERP and SCM systems integration: the case of a valve manufacturer in China, Inf. Manag. 45 (4), 2008, p. 233.

[6] C.V. Brown, Examining the emergence of hybrid IS governance solutions: evidence from a single case site, Inf. Syst. Res. 8 (March (1)), 1997, pp. 69–94.

[7] C.V. Brown, S.L. Magill, Alignment of the IS function with the enterprise: toward a model of antecedents, MIS Q. 18 (December (4)), 1994, pp. 371–403.

[8] J.C. Butler, J.S. Dyer, J. Jia, K. Tomak, Enabling E-transactions with multi-attribute preference models, Eur. J. Oper. Res. 186 (2), 2008, p. 748.

[9] L. Carrol, The Annotated Alice: Alice's Adventures In Wonderland And Through The Looking-Glass, New American Library, New York, 1960.

[10] R. Casadesus-Masanell, D.B. Yoffie, Wintel: cooperation and conflict, Manag. Sci. 53 (4), 2007, pp. 584–598.

[11] M. Chau, B. Shiu, I. Chan, H. Chen, Redips: backlink search and analysis on the web for business intelligence analysis, J. Am. Soc. Inf. Sci. Technol. 58 (3), 2007, p. 351.

[12] R. Chellappa, N. Saraf, Alliances, rivalry, and firm performance in enterprise systems software markets: a social network approach, Inf. Syst. Res. 21 (4), 2010, pp. 849–871.

[13] M.J. Chen, K.G. Smith, C.M. Grimm, Action characteristics as predictors of competitive responses, Manag. Sci. 38, 1992, pp. 439–455.

[14] M.J. Chen, Competitor analysis and interfirm rivalry: toward a theoretical integration, Acad. Manag. Rev. 21, 1996, pp. 100–134.

[15] S. Chu, H.T. Keh, Brand value creation: analysis of the interbrand-business week brand value rankings, Mark. Lett. 17, 2006, pp. 323–331.

[16] COBIT 5, COBIT 5 A Business Framework for The Governance and Management of Enterprise IT, ISACA, http://www.isaca.org/COBIT/Pages/default.aspx (accessed 24.09.13)

[17] R.G. Coyle, System Dynamics Modeling: A Practical Approach, Chapman & Hall, London, UK, 1996.

[18] K. Coyne, J. Horn, How companies respond to competitors: a Mckinsey global survey, McKinsey Q. April 2008, pp. 1–9.

[19] R.L. Daft, K.E. Weick, Toward a model of organizations as interpretation systems, Acad. Manag. Rev. 9, 1984, pp. 284–295.

[20] S. De Haes, W. Van Grembergen, R.S. Debreceny, COBIT 5 and enterprise governance of information technology: building blocks and research opportunities, J. Inf. Syst. 27 (1), 2013, p. 307.

[21] D. Demirhan, J. Varghese, S. Raghunathan, Information technology investment strategies under declining technology cost, J. Manag. Inf. Syst. 22 (3), 2006, pp. 321–350.

[22] P.J. Derfus, P.G. Maggitti, C.M. Grimm, K.G. Smith, The red queen effect: competitive actions and firm performance, Acad. Manag. J. 51 (1), 2008, pp. 61–80.

[23] W. Desarbo, A. Atalay, D. Lebaron, S. Blanchard, Estimating multiple consumer segment ideal points from context-dependent survey data, J. Consum. Res. 35 (1), 2008, p. 142.

[24] D.F. Feeny, B. Ives, In search of sustainability: reaping long-term advantage from investments in information technology, J. Manag. Inf. Syst. 7 (1), 1990, pp. 27–46.

[25] D.R. Fortin, R.R. Dholakia, Interactivity and vividness effects on social presence and involvement with a web-based advertisement, J. Bus. Res. 58 (3), 2005, pp. 387–396.

[26] C.M. Gayton, Commercial satellite imagery: CI, KM, and trade secret law, VINE 37 (2), 2007, pp. 192–206.

[27] R. Gibbons, Game Theory for Applied Economists, Princeton University Press, Princeton, New Jersey, 1992.

[28] T.J. Gilbride, G.M. Allenby, A choice model with conjunctive, disjunctive and compensatory screening rules, Mark. Sci. 23 (3), 2004, pp. 391–406.

[29] D. Grether, L. Wilde, An analysis of conjunctive choice: theory and experiments, J. Consum. Res. 10 (4), 1984, pp. 373–385.

[30] K. Han, Y.B. Chang, J. Hahn, Information technology spillover and productivity: the role of information technology intensity and competition, J. Manag. Inf. Syst. 28 (1), 2011, pp. 115–146.

[31] C.E. Helfat, M.A. Peteraf, The dynamic resource based view: capability lifecycles, Strateg. Manag. J. 24 (10), 2003, pp. 997–1010.

[32] P. Huang, T. Ouyang, S. Pan, T. Chou, The role of IT in achieving operational agility: a case study of Haier, China, Int. J. Inf. Manag. 32 (3), 2012, p. 294.

[33] ITIL, Information Technology Infrastructure Library, http://www.itil-officialsite.com/.(accessed 23.09.13).

[34] P. Karuppuswamy, G. Sundararaj, D. Elangovan, Application of computerised maintenance management system coupled with risk management techniques

for performance improvement of manufacturing systems, Int. J. Bus. Perform. Manag. 9 (1), 2007, pp. 7–21.

[35] M. Kearns, M.L. Littman, S. Singh, Graphical models for game theory, Proc. Of 17th Conf. on Uncertainty in Artificial Intelligence, Morgan Kaufmann, San Francisco, 2001.

[36] K.N. Lau, K.H. Lee, Y. Ho, Text mining for the hotel industry, Cornell Hotel Restaur. Adm. Q. 46 (3), 2005, p. 344., 19.

[37] M.B. Lieberman, D.B. Montgomery, First-mover advantages, Strateg. Manag. J. 9, 1988, pp. 41–58.

[38] W.T. Lina, B.B.M. Shao, The business value of information technology and inputs substitution: the productivity paradox revisited, Decis. Support Syst. 42 (2), 2006, p. 493.

[39] A. Lomi, E.R. Larsen, A. Ginsberg, Adaptive learning in organizations: a system dynamics-based exploration, J. Manag. 23 (4), 1997, pp. 561–582.

[40] E. Loukis, I. Sapounas, K. Aivalis, The effect of generalized competition and strategy on the business value of information and communication technologies, J. Enterprise Inf. Manag. 21 (1), 2008, pp. 24–38.

[41] Y. Lu, K. Ramamurthy, Understanding the link between information technology capability and organizational agility: an empirical examination, MIS Q. 35 (4), 2011, p. 931.

[42] J. Luftman, H. Zadeh, Key information technology and management issues 2010–11: an international study, J. Inf. Technol. 26 (3), 2011, pp. 193–204.

[43] J.T. Mahoney, J.R. Pandain, The resource-based view within the conversation of strategic management, Strateg. Manag. J. 13 (5), 1992, pp. 935–952.

[44] R.G. McGrath, Transient advantage, Harv. Bus. Rev. 91 (6), 2013, pp. 62–70.

[45] N. Melville, K. Kraemer, V. Gurbaxani, Review: information technology and organizational performance: an integrative model of IT business value, MIS Q. 28 (2), 2004, pp. 283–322.

[46] R. Narasimhan, S. Ghosh, D. Mendez, A dynamic model of product quality and pricing decisions, Decis. Sci. 24 (5), 1993, p. 893.

[47] S. Nazir, A. Pinsonneault, IT and firm agility: an electronic integration perspective, J. Assoc. Inf. Syst. 13 (3), 2012, pp. 150–171.

[48] R. Nelson, S. Winter, An Evolutionary Theory of Economic Change, Harvard University Press, Cambridge, MA, 1982.

[49] T.L. Powers, W. Hahn, Skill and resource based competitive methods: impact on firm performance, J. Serv. Mark. 16 (2), 2002, pp. 113–124.

[50] J. Quan, Q. Hu, P.J. Hart, Information technology investments and firms' performance – a duopoly perspective, J. Manag. Inf. Syst. 20 (3), 2004, pp. 121–158.

[51] G. Richardson, Modeling for Management, Dartmouth Publishing Co, Aldershot UK, 1996.

[52] N. Roberts, V. Grover, Leveraging information technology infrastructure to facilitate a firm's customer agility and competitive activity: an empirical investigation, J. Manag. Inf. Syst. 28 (Spring (4)), 2012, pp. 231–270.

[53] A.J. Robson, Complex evolutionary systems and the Red Queen, Econ. J. 115, 2005, pp. F211–F224.

[54] R.T. Rust, A.J. Zahorik, T.L. Keiningham, Return on quality: making service quality financially accountable, J. Mark. 59, 1995, pp. 58–70.

[55] V. Sambamurthy, R.W. Zmud, Arrangements for information technology governance: a theory of multiple contingencies, MIS Q. 23 (June (2)), 1999, pp. 261–290.

[56] L. Santamaría-Sánchez, M. Núñez-Nickel, S. Gago-Rodríguez, The role played by interdependences in ERP implementations: an empirical analysis of critical factors that minimize elapsed time, Inf. Manag. 47 (2), 2010, p. 87.

[57] R. Shortland, R. Scarfe, Data mining applications in BT, BT Technol. J. 25 (July (3–4)), 2007, p. 272., (6 pages).

[58] R.J. Slotegraaf, P.R. Dickson, The paradox of a marketing planning capability, J. Acad. Mark. Sci. 32 (4), 2004, pp. 371–385.

[59] R.J. Slotegraaf, C. Moorman, J.J. Inman, The role of firm resources in returns to market deployment, J. Mark. Res. 40 (3), 2003, pp. 295–309.

[60] K.G. Smith, C.M. Grimm, M.J. Gannon, Dynamics of Competitive Strategy, Sage Publications, London, 1992.

[61] K.G. Smith, W.J. Ferrier, H. Ndofor, Competitive dynamics research: critique and future directions, in: M. Hitt, R.E. Freeman, J. Harrison (Eds.), Handbook of Strategic Management, Blackwell, Oxford, 2001, pp. 315–361.

[62] R.E. Spekman, R.F. Bruner, L. Crowder, The Package War: Fedex vs. UPS, Case (Field) Product#: UV0015, 1996 (February 15).

[63] P. Tallon, Inside the adaptive enterprise: an information technology capabilities perspective on business process agility, Inf. Technol. Manag. 9 (1), 2008, pp. 21–36.

[64] P. Tallon, A. Pinsonneault, Competing perspectives on the link between strategic information technology alignment and organizational agility: insights from a mediation model, MIS Q. 35 (2), 2011, p. 463.

[65] C. Tan, X. Yang, H. Xu, An investigation of the word-processing software market war in South Korea: a game-theoretic approach, Inf. Manag. 47 (2), 2010, p. 96.

[66] D.J. Teece, G. Pisano, A. Shuen, Dynamic capabilities and strategic management, Strateg. Manag. J. 18 (7), 1997, pp. 509–533.

[67] M.E. Thatcher, D.E. Pingry, Understanding the business value of information technology investments: theoretical evidence from alternative market and cost structures, J. Manag. Inf. Syst. 21 (2), 2004, pp. 61–85.

[68] F. Ubeda, J.F. Wilkins, The Red Queen theory of recombination hotspots, J. Evol. Biol. 24 (March (3)), 2011, pp. 541–553.

[69] Val-IT, Val IT Framework for Business Technology Management, ISACA, http://www.isaca.org/Knowledge-Center/Val-IT-IT-Value-Delivery-/Pages/Val-IT1.aspx?utm_source=multiple&utm_medium=multiple&utm_content=friendly&utm_campaign=valit (accessed 23.09.13).

[70] A.H. Van de Ven, Running in packs to develop knowledge-intensive technologies, MIS Q. 29 (2), 2005, pp. 365–378.

[71] Ventana, Vensim PLE, Ventana Systems Inc., Harvard, Massachusetts, 2012, http://www.vensim.com.

[72] R. Vignesh, R. Suganthan, K. Prakasan, Development of CAD models from sketches: a case study for automotive applications, Proc. Inst. Mech. Eng. Part D J. Automob. Eng. 221 (D1), 2007, pp. 41–47.

[73] E.T.G. Wang, J.C.F. Tai, H.L. Wei, A virtual integration theory of improved supply-chain performance, J. Manag. Inf. Syst. 23 (2), 2006, pp. 41–64.

[74] H.J. Watson, B.H. Wixom, J.A. Hoffer, R. Anderson-Lehman, A.M. Reynolds, Real-time business intelligence: best practices at Continental Airlines, Inf. Syst. Manag. 23 (1), 2006, p. 7.

[75] M. Yasai-Ardekani, P.C. Nystrom, Design for environmental scanning systems: tests of a contingency theory, Manag. Sci. 42 (2), 1996, pp. 187–204.

[76] M. Zain, R.C. Rose, I. Adbullah, M. Masrom, The relationship between information technology acceptance and organizational agility in Malaysia, Inf. Manag. 42 (6), 2005, pp. 829–839.