Cooperating to Commercialize Technology: A Dynamic Model of Fairness Perceptions, Experience, and Cooperation

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Abstract

Technology entrepreneurship is an important driver of economic growth, though entrepreneurs must maintain cooperative ties with the owners of any technology they hope to bring to market. Existing studies show that fairness perceptions have a great influence on this cooperation, but no research investigates its precise mechanisms or dynamic patterns. This study explores the development of 17 ventures that cooperated with a university-owner of technology and thereby identifies different cooperation patterns in which fairness perceptions influence the degree of cooperation. These perceptions also change over time, partly as a function of accumulated experience and learning. A system dynamics model integrates insights from existing literature with the empirical findings to reveal which cooperation mechanisms relate to venture development over time; the combinations of individual experience, fairness perceptions, and market circumstances lead to four different patterns. This model can explain changes in entrepreneurial cooperation as a result of changes in fairness perceptions, which depend on learning effects and entrepreneurial experience. Each identified cooperation pattern thus has implications for research and offers insights for practitioners who need to manage relationships in practice.

1. Introduction

Efforts to commercialize university-based inventions encourage economic growth, because technology ventures enjoy a good likelihood of evolving into high growth firms (Mueller 2006, Shane 2004). For the entrepreneurs who bring such a technology to market, cooperating with the university is key to ensure their venture development, sustainability, and competitive advantage (Rothaermel and Thursby 2005, Shane 2002), especially when those universities provide crucial resources such as property rights, human capital, offices, lab facilities, or funding. Existing research describes antecedents and outcomes of cooperation and demonstrates that contractual and governance forms matter (Alvarez and Parker 2009, Reuer et al. 2006), even if subjective factors, such as fairness perceptions, appear even more important (Husted and Folger 2004, Sapienza and Korsgaard 1996, Sommer and Loch 2009). Yet we still lack insight in the dynamics of cooperative relationships between resource owners (e.g., universities) and entrepreneurs (Ariño and De la Torre 1998, Ariño et al. 2008, Ness 2009). As entrepreneurial cooperative relationships unfold over time, external events can affect interactions and fairness perceptions, especially as the parties accumulate new experiences and learn new behavior. Therefore, studying cooperation as dynamic behavior over time is vital for understanding entrepreneurial cooperation and the interventions that can overcome the limitations of standardized procedures that tend to break down in this context (Shane 2004, Sommer and Loch 2009).

This study investigates cooperation between entrepreneurs and a university where they acquired the intellectual property of the technological invention they hope to exploit. The resulting university spin-offs are key mechanisms for commercializing university-owned technologies (Bercovitz and Feldman 2006) and realizing economic growth (Mueller 2006), in which context the university usually provides resources to start the venture, acquire intellectual property rights, develop the technology, and obtain access to facilities. In such

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alliances, fairness perceptions significantly influence the cooperation between the entrepreneurs and the university, yet no research investigates the precise mechanisms and different patterns of their cooperative dynamics (Ambos et al. 2008, Feldman et al. 2002, Rappert et al. 1999).

We adopt a process perspective and investigate which feedback and causal mechanisms determine how fairness perceptions affect this form of cooperation. Our conceptualization of the process is grounded in an in-depth literature review; we then gather empirical observations of 17 spin-off ventures. In turn, we can identify several cooperation patterns, including some counterintuitive patterns in which perceptions of unfairness shift to a sense of fairness, or vice versa, resulting in either cooperative or uncooperative behavior that has serious performance implications. We propose a system dynamics (SD) model of the feedback mechanisms and reinforcing causal loops. As its center, this model highlights how changing fairness perceptions drive more cooperation, particularly with the accumulation of experience that results in new behaviors and adjusted perceptions. In contrast, if learning is prevented, the relationship appears increasingly unfair, cooperation deteriorates, and venture development gets delayed. Our study specifies the influential functions of experience, fairness perceptions, and cooperation for technology commercialization. We also model possible interventions in deteriorating cooperation patterns, showing that involving experienced entrepreneurs early in the commercialization process may turn uncooperative behavior into more productive interactions.

2. Fairness Perceptions and Entrepreneurial Cooperation

2.1. Need for Cooperation

When new ventures exploit university-owned technology, their relationship with the university is vital. Shane (2002) shows that university-owned inventions tend to be embryonic and highly innovative, such that the inventor's cooperation for further

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development is crucial for commercialization. The inventor might serve as the lead entrepreneur or member of venture team in a technology spin-off, though in some cases, the inventor has just an informal position in a venture run by an external entrepreneur (Franklin et al. 2001). Regardless of the inventor's exact position, the venture must cooperate closely with his or her source university, to support the sharing of tacit knowledge about the research that led to the invention and to develop follow-up products (Jensen and Thursby 2001).

Academic entrepreneurs also usually must enter into a formal relationship with the university to acquire financial resources and ensure intellectual property (IP) protection (e.g., an exclusive license from the university). A formal relationship also enhances the credibility of the venture. Accordingly, research shows that more cooperative and formal venture–university relationships exert positive influences on new venture performance (Rothaermel and Thursby 2005, Vohora et al. 2004), result in more innovative output at lower costs (George et al. 2002), and lead to faster new venture establishment (Müller 2010).

2.2. The Crucial Role of Fairness

After deciding to exploit a particular university-owned technology through a new venture, academic entrepreneurs must negotiate with the university to acquire the IP rights (usually with a license) and design the revenue sharing, because in most countries, the technology will be owned by the university (Stevens and Bagby 2001). The stressful bargaining process can reduce entrepreneurs' motivation and perceptions of fair treatment (Nicolaou and Birley 2003, Rappert et al. 1999), which in turn might influence their cooperative behavior. If they are sufficiently upset by the negotiations, they might even terminate the cooperation or pursue litigation (Feldman et al. 2002). Thus the degree of cooperation largely depends on the degree of perceived fairness, which affects commitment, trust, and social harmony and leads to cooperative or uncooperative behaviors (Kim and Mauborgne 1998, Ring and Van de Ven 1994). The degree of perceived fairness in turn depends on the surrounding conditions,

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interactions, and outcomes in the alliance (Kumar and Nti 1998). Fairness perceptions should be particularly important with regard to entrepreneurs, who lack organizational commitment to the university and instead must be personally involved in cooperation.

Existing research distinguishes four fairness dimensions—distributive, procedural, interactional, and informational (Colquitt 2001)—though the effect of procedural fairness on cooperation is most frequently studied (Griffith et al. 2006, Sommer and Loch 2009). Increases in fairness lead to better cooperation (Amaral and Tsay 2009, Griffith et al. 2006, Sommer and Loch 2009) and better venture performance. For example, in a study of the cooperative relationships between venture capitalists and entrepreneurs, Busenitz et al. (2004) find that procedural fairness (the perceived fairness of the process) relates positively to long-term venture performance, and Sapienza and Korsgaard (1996) observe that procedural fairness helps explain the degree of cooperation between entrepreneurs and investors. Similarly, perceived fairness increases cooperation between subsidiaries and corporate management, resulting in higher performance (Kim and Mauborgne 1998), and in a corporate context, it enhances a firm's ability to exploit entrepreneurial opportunities by increasing the amount and quality of knowledge sharing and learning (De Clercq et al. 2010). Thus, fairness perceptions influence the quality of social interactions.

Fairness perceptions influence human behavior especially in settings marked by unequal power distributions, such as when one partner has less ability to assert preferences. Fair treatment and procedures give weaker partners a feeling of indirect control and encourage them to accept even somewhat adverse outcomes (Lind and Tyler 1988, Sapienza and Korsgaard 1996). In contrast, perceptions of unfair treatment result in resentment and adverse behavior, such as sabotage or uncooperative actions, regardless of the potential for detrimental consequences for the venturing process (Kim and Mauborgne 1998, Pillutla and Murnighan 1996, Sommer and Loch 2009).

2.3. Cooperation as a Dynamic Process

To gain insights into the dynamics of cooperative (entrepreneurial) relationships, Ring and Van de Ven (1994) conceptualize a sequence of negotiation, commitment, and execution stages that rely on assessments of an ongoing interaction's efficiency and equity. By emphasizing both fairness and efficiency, this conceptualization balances hard (e.g., contracts) and soft (e.g., fairness perceptions) processes. Doz (1996) also proposes that cooperation depends on the initial conditions that define the tasks, interface structure, and expectations. Partners then cycle through a sequence of learning, reevaluation, and re-adjustment, which enables them to evaluate the relationship's efficiency, fairness, and adaptability. The reevaluation stage in particular highlights perceived fairness, cooperation progress, and speed and thus can result in adjustments to cooperative conditions and processes—whether for the better or not. For example, if early expectations indicated good success probabilities, negative reevaluations due to slow development might disrupt cooperation.

Perceptions of fairness and venture progress also change over time and have varying effects on the cooperation between small university spin-offs and their large university partners (Feldman et al. 2002, Sommer and Loch 2009). Although we know that perceived fairness increases cooperation and related performance, it remains unclear how fairness perceptions change over time and thereby vary in their effects on cooperation and performance. Our detailed study of fairness perceptions and cooperation dynamics aims to reveal the mechanisms underlying these interactions and create insights for managing them.

Accordingly, in Figure 1 we integrate these research findings and display the role of fairness perceptions and subsequent entrepreneurial cooperation in three partly overlapping adjustment, reevaluation, and learning cycles (cf. Ariño and De la Torre 1998, Doz 1996). Existing literature treats these three cycles as separate mechanisms; we instead stress their

cumulative and reinforcing nature by conceptualizing them as partly embedded causal loops.

All the relationships in Figure 1 are positive. In the *adjustment cycle* (light grey arrows),

accumulated experience affects both performance and perceived performance, which initiates

a positive change in fairness perceptions. Perceived fairness exerts a positive effect on

cooperative behavior, which influences the pace of key startup and commercialization events.

This execution of startup events then increases experience, which closes the adjustment cycle.

The *reevaluation cycle* (dark grey arrows) is partly embedded therein but includes a direct

effect of the pace of startup events on perceived performance. That is, as more key startup

events get executed, more progress is made, and the perceived performance of the venture

improves, which triggers an increase in fairness perceptions and then results in increased

cooperation. Finally, in the *learning cycle* (black arrows), the execution of startup events

leads to increased experience, which directly affects cooperative behavior and then influences

the pace of events.

------ Insert Figure 1 about here --------

3. Empirical Cooperation Patterns

3.1. Empirical Data and Analysis

The empirical data that inform our model pertain to new ventures commercializing

technology from Eindhoven University of Technology in The Netherlands. This university

stimulates the creation of new ventures proactively, with the goal of commercializing

university inventions, so it has established various procedures and rules to guide new

venturing processes, such as norms for the negotiation process and standard agreements

between the university and entrepreneurs. These rules attempt to create smooth

commercialization processes by preventing extended negotiations and establishing

expectations for the inventors and (future) entrepreneurs.

We selected a sample of 17 new ventures begun by academic entrepreneurs from the database maintained by the technology transfer office (TTO) at the university, in consultation with the TTO staff. The sample features theoretically relevant differences, including the industry targeted, the academic or industry experience of the entrepreneurs, and the success of the venture. Yet, the small sample enables our in-depth comparison of each case and examination of its cooperative dynamics (Eisenhardt 1989, Lichtenstein et al. 2006, Van de Ven and Engleman 2004).

The data came from two main sources: (1) open-ended interviews with the entrepreneurs and university officials and (2) archival data. We conducted 29 face-to-face interviews with the lead founders, as well as 13 interviews with university and TTO officials, which we used to discern the institutional environment of the university. All interviews were recorded and fully transcribed. The archival data sources included company-related documents and performance data, such as business plans and annual reports, as well as contracts with the companies. We also collected newspaper articles, interviews, brochures, and online information about the companies.

Our analyses of the interviews with the academic entrepreneurs enabled us to identify the key startup and commercialization events. We employed the coding technique developed by Van de Ven and Poole (1990) to code events that must occur for a venture to become an independent and viable company (Lichtenstein et al. 2007). The key events include filing the first patent, registering the company, signing the contract with the university, starting production, acquiring investments, and establishing an agreement with a first client. We also coded context characteristics, including market complexity (i.e., volatility and market response), and individual-level characteristics, such as experience. We coded the four dimensions of fairness perceptions (Colquitt 2001), but they all had similar effects on cooperation, so we proceeded with a single, overall fairness construct. Two coders,

unfamiliar with the study, confirmed the reliability of the final coding. We then triangulated

the interview codes with other data sources, such as e-mail conversations and press releases.

Next, we created and analyzed graphical representations of the event series, including the

time between events, for each of the 17 cases, to identify any differences in the venture

startup patterns (Langley 1999). We then related the identified cooperation patterns and their

underlying events with the coded fairness perceptions, contextual characteristics, and

individual-level conditions. By using the throughput time of events, we established a

relationship among fairness perceptions, cooperative behavior, and venture performance in

terms of progress.

3.2. Empirical Findings

Our empirical analysis reveals three cooperation and new venture development patterns, each

of which includes two phases of interaction. For example, the unfair–fair pattern indicates

that the entrepreneur initially perceived the relationship as unfair but then grew to regard it as

fair. Two key differences in venture and context characteristics influenced these fairness

perceptions and thus the cooperation patterns: the degree of initial experience possessed by

the entrepreneur (low or high) and the complexity of the market in which the entrepreneur

operates (low or high). Combining these two differences result in four possible patterns, but

we empirically observed only three (see Table 1). The fourth possible pattern thus appears

unusual; it does not emerge in any of our 17 cases. In Figure 2 we depict the accumulation of

startup and commercialization events as a function of time for each of the three empirically

observed patterns. Higher curves indicate that the events accumulated quickly. As more key

startup events occur within a particular time period, venturing progress increases in speed.

------ Insert Table 1 and Figure 2 about here --------

The first pattern, which we call *steady development* (fair–fair), features startup events

that occur faster than in the other two observed patterns. For example, the establishment of

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the legal entity and strategic cooperation with external parties both start early, and entrepreneurs perceive the university's procedures and policies, as well as the (negotiation) behavior exhibited by its representatives, as consistently fair. As one founder noted, "It is especially important that we found something that was satisfactory to everybody.... They may get their 200K [in royalties]. That's quite easy, also because it is favorable for both parties. When the university sees something coming back, we will probably get more from them as well." That is, cooperation with the university appears essential for the venture's development, so the entrepreneurs work hard to maintain good working relationships. Another founder explained, "I prefer to be embedded within the research group. That I could talk with researchers at the coffee table. That's of much value for me." The ventures following this pattern in turn show steady development and continuous growth; the critical events in their development curves are the filing of their first patent and the start of production. Their markets exhibit relatively low complexity and volatility. Finally, an essential condition is the degree of (market and entrepreneurial) experience of the founders, which emerges in their fairness evaluations: "We just make agreements in conformance with market standards. That is the most effective deal."

In the second pattern, *increased cooperation* (unfair–fair), the entrepreneur requires significantly more time to complete key startup events. In particular, the first five startup events take significantly more time than in the steady development pattern, but over time, the pace increases. Initially entrepreneurs perceive the relationship as unfair, such that "The TTO director says: if a spin-off earns twenty Ferrari's, we would like to get one as well.… But he wanted to have 15% [of the shares], that makes it three Ferraris! Then, I start thinking: that's just unfair." This perception reflects the power imbalance between the entrepreneur and the university: "You easily get screwed. The university has the most powerful position." It also slows progress in negotiations, which spills over to affect other startup events. For example,

ventures often need IP agreements with the university to attract investments. However, soon after they finalize these negotiations, fairness perceptions turn more positive. Entrepreneurs learn to perceive the agreement and relationship as fair, so they increase their cooperation with the university, and venture development progresses at a moderate pace (i.e., increasing slope after month 18 in Figure 2). As an important individual-level condition, these entrepreneurs (mostly doctoral students or recent graduates) appear relatively inexperienced. Their changing perceptions, cooperation, and performance indicate their learning curves, as one founder reflected in a second interview, just after he had finished negotiations: "We were maybe a bit naive in the beginning.… More experience would definitely have helped.… The most important difference is: we were quite negative in the beginning and now we're more positive." As the surrounding market has relatively low complexity, this pattern allows for learning time, because there is no need for quick action to meet changing customer preferences or to deal with changing competitive landscape. Yet their minimal experience causes entrepreneurs to perceive even these markets, with their relatively low complexity, as difficult, which helps explain why the initial events take so much time.

Finally, in the *decreased development* pattern (fair–unfair), entrepreneurs initially develop the venture quickly and in close cooperation with the university after a short period of negotiations. In the first phase, the entrepreneurs perceive the university's rules and behavior as fair, but by the second or third investment round, their perceptions begin to change, and they regard their previous agreement and renegotiations as unfair. Therefore, they decrease their cooperation with the university, because they believe, for example, "The average VC [venture capitalist] does not ask so many clauses as the university.... The approach is: as the university gets such a percentage for actually nothing, what should I tell this VC three months later? That the company's value has increased twenty times? That doesn't work. It is just not correct." The specific events surrounding changing perceptions

suggest that (re)negotiations often take place in difficult market circumstances, such as a lack of positive responses from customers or industry crises. When they reduce their cooperation, the entrepreneurs must find "better" partners, which delays the commercialization process. This pattern is common among founders with substantial business experience, who experience the university environment as "not professional" or lacking in "business-like manners." Yet their experience also seems to prevent them from learning from the changing circumstances to achieve fruitful interactions with the university.

4. Model Description

Some patterns are more likely to be delayed, but a simple explanation that relies solely on high market complexity and low experience is insufficient. For example, we find a mixture of quick and delayed venture development in two patterns (see Table 1), which implies the need for insights in dynamic patterns. Accordingly, we develop a system dynamics (SD) model that describes the complex interrelationships of new venturing processes, fairness perceptions, entrepreneurial experience, and cooperation dynamics. This method can analyze situations that involve multiple and interacting processes, delays, accumulations, and other nonlinear effects, such as feedback loops and thresholds (Davis et al. 2007), and it appears extensively in prior research (e.g., Akkermans and Vos 2003, Croson and Donohue 2006, Garcia et al. 2003, Georgiadis et al. 2009, Größler et al. 2008, Oliva and Sterman 2001, Repenning and Sterman 2002). Also entrepreneurship researchers have started to use SD modeling, to describe venture development from opportunity identification to exit (Yearworth 2010), to explore the effects of e-commerce strategies (Bianchi and Bivona 2002), and to understand the growth of biotech start-ups (Grossmann 2003). Our SD model extends this literature by developing and simulating a model of the cooperation dynamics of entrepreneurial firms and by using a modeling approach that not only uses empirically grounded results (see Yearworth 2010) but also combines these results with literature based

relationships. The key concepts of our SD model are based on our literature review (see

Figure 1), though the model behavior and the value of the exogenous variables are based on

our empirical analysis (see Table 1). Thus, our empirically grounded model provides a logical

and coherent explanation of interrelationships and resulting multi-ordered dynamics of the

different processes. We provide a full description of the model, including model equations

and the values of the exogenous variables, in a separate model documentation appendix,

available upon request.

4.1. Main Model Equations

We provide a stylized version of the simulation model in Figure 3, which contains three

reinforcing cycles: adjustment, reevaluation, and learning. For clarity, we detail the model in

the reverse sequence, starting with the shortest (i.e., learning) cycle (black arrows in Figure

3).

----- Insert Figure 3 about here -------

4.1.1. Modeling the Learning Cycle

The learning cycle begins with the execution of the startup and commercialization events

(lower left corner, Figure 3). The event execution rate (*eer*) refers to the number of startup

events executed per month; it implies the flow from events that are currently being

undertaken, or Events in Execution (*EiE*), to the stock of completed or Executed Events (*EE*).

Initially of course, the *EiE* stock is full, because all the events have yet to be executed. The

EE stock contains a single event: the invention. As the cooperation progresses, more events

get executed, *EiE* is depleted, and *EE* increases (Equation 1). As our empirical observations

show a total number of 16 unique startup events per case, EE will never rise above 16. To

measure *eer*, we multiply the number of startup events in execution (*EiE*) by the degree of

cooperative behavior (*CB*) (Equation 2). Thus as *CB* increases, *eer* increases, because more

cooperative behavior should shorten the event execution time (*eet*) (Equation 3). Thus,

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$$\frac{d}{dt}EE = eer \quad \text{and} \quad \frac{d}{dt}EiE = -eer, \tag{1}$$

$$eer = EiE \cdot CB \text{ , and} \tag{2}$$

$$CB = \frac{1}{eet}. \tag{3}$$

Every executed event also adds to the entrepreneur's accumulated experience. Therefore, *eer* directly influences the experience rate (*iex*) (Equation 4). However, experience could decrease if an entrepreneur forgets about past events (*dex*). Therefore, to determine the relative experience of an entrepreneur, compared with the experience possessed by other entrepreneurs (*relEx*) (Equation 5), we measure the ratio of Experience with Events (*ExE*) to a reference level of experience (*refEx*). This reference level equals the maximum experience an entrepreneur can attain in this industry, ranging from 0 (no experience) to 1 (maximum experience). Thus,

$$\frac{d}{dt}ExE = iex - dex = eer - dex \text{ , and} \tag{4}$$

$$relEx = \frac{ExE}{refEx}. \tag{5}$$

We also recognize that more relative experience (*relEx*) should reduce the execution time, because according to learning curve theory, productivity rises by a given percentage as experience levels increase (Sterman 2000; see also Lapré et al. 2000, Wiersma 2007). We define the productivity increase that results from learning in our study as a lead-time based on learning (*ll*) construct:

$$ll = mcf \cdot nl \cdot relEx^{elc}. \tag{6}$$

We designate the normal lead-time (*nl*) as equal to the shortest event lead-time, which occurs when the entrepreneur has maximum experience. Across industries, lead-times fall by 10% to 30% with twice the amount of cumulative experience (Sterman 2000). However, our modeled process is not very repetitive, so we assume that smaller lead-time reductions result from adding experience. Specifically, for every doubling of *ExE*, we assume *ll* declines by 10%, so

the exponent of the learning curve (*elc*) equals –0.15. This constant exponent describes the strength of the learning curve; because it is negative, a higher level of relative experience induces a shorter lead-time based on learning. Finally, *ll* should be positively influenced by a constant that represents the market complexity factor (*mcf*). At the same experience level, *ll* should be longer in complex rather than simple markets.

Beyond the learning effect, the time needed to execute an event (*eet*) depends on perceived fairness (*PF*):

$$eet = ll / PF.$$ (7)

That is, if an entrepreneur perceives higher fairness, the time needed to execute an event should be shorter. This reduced time then leads to cooperative behavior (*CB*), which closes the learning cycle. Thus the learning loop has two negative links: between relative experience and lead-times based on learning, and between event execution time and cooperative behavior. The even number of negative links implies positive, or reinforcing, overall behavior of the loop.

4.1.2. Modeling the Reevaluation Cycle

In the reevaluation cycle (dark grey arrows, Figure 3), the number of executed startup events (*EE*) determines the progress of the venture (*pv*), which in turn influences its perceived performance, according to the entrepreneur (*PP*). The progress of the venture is measured by comparing the actual progress in terms of *EE* with the planned progress. When the actual progress falls behind the expected schedule, *pv* decreases. Because perception changes take time, we model *PP* as an adaptive expectation; it gradually adjusts to the actual progress of the venture (Sterman 2000) through changes in perceived performance (*cPP*). Initially the entrepreneur has difficulty assessing venture performance, because few events have been executed. Thus perceived performance initially depends on the entrepreneur's relative experience (*relEx*). Over time, more events get executed, and *PP* is increasingly influenced

by venture progress, so we predict that the weight of experience (*we*) decreases over time (from 1 to 0). In terms of our causal loops, this means that in the beginning the adjustment-loop (with *relEx*) and the learning-loop are the drivers of the model's behavior. Over time, the influence of *relEx* decreases because *we* decreases and as a result the reevaluation-loop (with *pv*) and the learning-loop will determine model behavior. The time required to adjust *PP* (perceptions) to actual values (determined by *pv*, *relEx*, and *we*) then depends on the perception adjustment time (*pat*):

$$cPP = \frac{d}{dt}PP = \frac{-PP + (we \cdot relEx + (1-we) \cdot pv)}{pat} \quad . \tag{8}$$

Performance perceptions also directly influence perceived fairness (*PF*), again as an adaptive expectation: It takes time before the entrepreneur recognizes performance, so *PF* lags *PP* by a certain time (*pat*):

$$cPF = \frac{d}{dt}PF = \frac{-PF + PP}{pat} \quad . \tag{9}$$

The reevaluation cycle continues from *PF* to *eet*, *CB*, *eer*, *EE*, *pv*, and *cPP*—relationships that we described previously, so we refer readers back to Equations 1–8 for their explanations.

4.1.3. Modeling the Adjustment Cycle

Finally, the adjustment cycle (light grey arrows, Figure 3) starts with the rate at which events get executed; continues with increasing experience, perceived performance, perceived fairness, and event execution time; and closes with the impact of cooperative behavior on the event execution rate. See Equations 1–9.

4.2. Settings and Model Fit

Our empirical results show that particular combinations of experience and market complexity produce three patterns in real-world alliances (see Table 1):

- Steady development (fair–fair). The fixed pace at which events are executed results in quick venture development (high experience, low complexity).

- Increased cooperation (unfair–fair). The event execution rate is slow at first but then speeds up (low experience, low complexity).

- Decreased cooperation (fair–unfair). The fast event execution rate in the beginning eventually slows down (high experience, high complexity).

Although we did not observe the fourth possible pattern in our empirical analysis, we consider it for theoretical completeness, namely,

- Unstable development (unfair–unfair). Events are executed slowly, both at first and in the end (low experience, high complexity).

For each pattern, we use our SD model to recognize the feedback mechanisms and reinforcing causal loops that drive them. To ensure that we can replicate actual behaviors with our model, we assess its performance statistically through a comparison with our empirical data pertaining to executed events, or *EE* (available for the first three scenarios). The comparison is based on Theil's inequality statistics (Figure 4, Panel B), such that we can evaluate the fit between actual (Figure 2) and simulated (Figure 4, Panel A) *EE* behavior (Sterman 2000). Specifically, we divide the root mean square error into three components: bias (i.e., actual and simulated data have different means), unequal variation (actual and simulated data have different variances), and unequal covariation (actual and simulated data are imperfectly correlated). If the error is small and unsystematic (concentrated in unequal variation or covariation), the model can endogenously generate the behavior that marks the observed system (Sterman 1984).

We find a good fit between actual and simulated behavior (Sterman 2000). In general, the errors are concentrated in unequal variation or covariation. Although the bias associated with the increased cooperation pattern is somewhat large (0.45), the bias is nearly zero for the

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other patterns, which implies the former value is probably due to acceptable assumptions that do not compromise the model as such (Sterman 1984). The graphs in Figure 4, Panel A, also confirm the robustness of our results. That is, differences are relatively small between the simulated increased and decreased cooperation patterns, but the crucial patterns emerge. For example, in the simulated decreased cooperation pattern (black solid line, Figure 4, Panel A), the number of initially executed events is slightly higher than the number in the increased cooperation pattern (dark grey solid line), which implies a higher event execution rate. Then after month 26, the situation reverses.

With Figure 5, we undertake a visual inspection of the effects of fairness perceptions. Although we lack time-series data regarding perceived fairness behavior (*PF*), quotes from our interviews reflected fairness perceptions in all three scenarios, including changes over time, so we expect simulated *PF* to reflect these quotes. According to Figure 5, Panel A, the model simulation attains satisfactory results that align with the empirical data: Fairness is always high ($\geq$0.5) in the steady development pattern, grows in the increased cooperation pattern, declines in the decreased cooperation pattern, and is always low (<0.5) in the hypothetical unsteady development pattern.

----- Insert Figure 4 and Figure 5 about here -------

5. Model Results: Four Cooperation Patterns

From our theoretical model derived from prior literature (Figure 1) and our simulation model based on our empirical study (Figure 2), we derive a narrative to explain how the cooperation between an entrepreneur (small partner) and a university (large partner) unfolds.

5.1. Steady Development Pattern (Fair–Fair)

In this scenario, a relatively experienced entrepreneur starts to commercialize a university-owned technology through a new venture in a market with minimal complexity. The entrepreneur has started ventures before and knows what to expect from the university;

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expectations about the time needed to execute all necessary events also are reasonable. The entrepreneur's initial expectation is that the negotiations will be fair (light grey solid line, Figure 5, Panel A), and this positive perception smoothes communication processes and cooperative behavior, which shortens the event execution time (Figure 5, Panel B) and speeds up the event execution rate. As more events get executed, the entrepreneur's experience steadily increases (Figure 5, Panel C), and through this learning curve, execution time per event falls (Figure 5, Panel B). Then the reinforcing loop with increased fairness perceptions (Figure 4, Panel A) leads to even more effective cooperation and further reductions in event execution time. The venture performance is consistently good (Figure 5, Panel D) and fairness perceptions persist throughout the process (Figure 5, Panel A).

5.2. Increased Cooperation Pattern (Unfair–Fair)

When a relatively inexperienced entrepreneur wants to start commercializing a university technology in a market with relatively low complexity, his or her lack of experience (dark grey solid line, Figure 5, Panel C) exaggerates the power imbalance with the large university and thus creates low initial fairness perceptions (Figure 5, Panel A). In turn, these inexperienced entrepreneurs are reluctant to cooperate, so communication and cooperation take more time and lengthen the event execution time (Figure 5, Panel B). However, the relative simplicity of the market still allows events to be executed, so the progress of the venture never falls below 75% (Figure 5, Panel D). Furthermore, because the entrepreneur is at the start of a learning curve, every event makes a high marginal contribution to his or her experience level (Figure 5, Panel C). After executing about half of the necessary events, the learning effects come into play; the turning point after 8 of the 16 start-up events is based on our empirical study. We find that reaching a final agreement with the university about IP (which is the ninth event, on average) prompts a shift in fairness perceptions. The augmented learning thus increases fairness perceptions (Figure 5, Panel A), ensures cooperative

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behavior, and shortens event execution time (Figure 5, Panel B), which advances the venture's progress (Figure 5, Panel D).

5.3. Decreased Cooperation Pattern (Fair–Unfair)

In this scenario, an experienced entrepreneur enters a relatively complex market with a university-owned technology. This entrepreneur is very optimistic: Having started new ventures successfully before, why should this one fail? Initially then, the fairness of the interactions with the university seems high (black solid line, Figure 5, Panel A). However, the complexity of the selected market creates some problems, leading to longer than expected event execution times (Figure 5, Panel B) and a sense of stagnation in perceived progress (Figure 5, Panel D). Because the entrepreneur has already reached the end of his or her learning curve, experience increases minimally (Figure 5, Panel C), so new events have limited influence on event execution time, which barely gets reduced at all during the process (Figure 5, Panel B). Progress falls farther and farther behind the intended schedule, and the entrepreneur starts to regard the process as inflexible and unfair. The cycle grows vicious: Lower perceived fairness increases event execution time, which reduces progress and decreases perceived fairness even more.

The behavior of this pattern (first fairness increases and later it decreases) deserves some clarification as only reinforcing loops drive this behavior. The lack of venture progress in the beginning of the decreased cooperation pattern only has a minor effect on Perceived Performance (*PP*) as a result of the relatively large weight of experience (*we*). As a result, in the beginning the adjustment-loop dominates and all variables in this loop are increasing. Although *pv* is quite low, an increasing *relEx* does compensate for this effect, leading to an overall positive effect on *PP*. However, *we* decreases over time and the reevaluation-loop becomes stronger over time, which causes that the decreasing venture progress influences *PP*

20

negatively. Even though the actual progress (in terms of *EE*) can be increasing, there is a negative effect on *pv* as long as the actual progress is below the planned progress.

5.4. Unsteady Cooperation Pattern (Unfair–Unfair)

We imagine, in this hypothetical pattern, that an inexperienced entrepreneur starts to commercialize university-owned technology in a highly complex market. Low initial fairness perceptions (black dotted line, Figure 5, Panel A) and high market complexity induce a long initial event execution time (Figure 5, Panel B). The slow progress barely adds to the entrepreneur's experience; after week 26, the time needed to execute an event becomes so long that the entrepreneur even starts to forget, leading to reduced experience (Figure 5, Panel C). We observe another vicious cycle: Long event execution times lead to a minor increase in experience, which results in little learning and slower progress, which negatively affect perceived fairness and thereby increases event execution time even more.

As this unsteady development pattern was not validated by our case study due to a lack of empirical observations of this pattern, we analyzed the pattern by sensitivity analyses. We tested the robustness of the pattern by changing the values of two exogenous variables. Our analyses show that the pattern is robust to these changes (see the model documentation appendix).

5.5. Intervention Scenarios: From Vicious to Virtuous Cycles

How can ventures in these latter two deteriorating patterns possibly succeed? Our SD model enables us to explore whether it is possible to turn vicious cycles into virtuous ones. Of the various interventions possible—such as hiring technology transfer officers with more expertise (Lockett and Wright 2005), shifting to a less complex market, or adapting the business model (Degroof and Roberts 2004)—we consider the option of adding experienced entrepreneurs to the venturing team (Franklin et al. 2001). We model such additions as a sudden increase of entrepreneurial experience (*ExE*) at different points in time, namely, at 6,

12, 18, and 24 months. For each time, we determine the minimum amount of extra experience needed to halt the vicious cycle, increase cooperation, and enhance venture progress.

----- Insert Figure 6 about here -------

We show the results of these interventions in Figure 6. Specifically, in Panel A, we find that it is possible to halt the vicious cycle in the decreased cooperation pattern by involving an experienced entrepreneur, but the amount of extra experience required grows exponentially over time. In month 6, adding 8 events to the stock of experience (*ExE*) is sufficient to turn the collaboration into a positive interaction. Our reference experience level (*refEx*) is set to 100 events, so the addition implies involving another experienced entrepreneur for only 8% of the week. In month 24 though, the necessary experience jumps to 274 events—equivalent to adding almost three, full-time, experienced entrepreneurs. Panel B indicates that halting the hypothetical unsteady development pattern would be even more difficult: At month 6, we would need an extra experience of 43 events to turn the collaboration into a positive interaction. By month 12, this intervention can no longer succeed, regardless of how much experience the venturing team adds, and the vicious circle becomes inescapable.

6. Discussion

The SD model, which extends existing literature and is based on empirical data, reveals interactions over time among feedback mechanisms and causal loops: the accumulation or loss of entrepreneurial experience (mediated by a learning curve), changing fairness perceptions, increased or decreased cooperation, and venture development (which is associated with venture success, Lichtenstein et al. 2007). In contrast, existing literature on university spin-offs and entrepreneurial cooperation has primarily studied cooperation from a cross-sectional perspective (Lichtenstein et al. 2007, Reuer et al. 2006, Rothaermel et al. 2007) and therefore cannot offer detailed explanations for why some cooperation processes

are more or less difficult (cf. Müller 2010). Unlike most interfirm collaborations, entrepreneurs face significant uncertainty and must deal with individual-level fairness perceptions when they ally with universities—features that are hard to manage with standardized contracts and procedures (Shane 2004, Sommer and Loch 2009). We contribute to extant literature by providing a causal, dynamic understanding of how changing fairness perceptions influence entrepreneurial cooperation and technology commercialization processes. In particular, we show that no single critical event triggers increased or decreased cooperation; rather, it depends on learning effects and initial levels of and increasing entrepreneurial experience. Each identified cooperation patterns thus has implications for research, as well as important insights for practitioners, who should take individual-level perceptions and experiences of the entrepreneurs into account when managing such relationships.

The steady development pattern (fair–fair) exemplifies the reinforcing effect of experience, fair perceptions, effective cooperation, and smooth technology commercialization processes. Most studies imply this pattern: A high degree of relevant experience leads to high degrees of perceived fairness (Müller 2010), better cooperation, and more successful venturing (Grandi and Grimaldi 2005, Lee and Tsang 2001, McGee et al. 1995). However, our study also reveals that the experience effect is dynamic and cumulative, such that more relevant experiences and positive learning improve cooperation. In a practical sense, venturing teams should aim to include experienced entrepreneurs, who can smooth the process, especially if they have cooperated with the focal university before.

The increased cooperation (unfair–fair) pattern offers a new finding by showing that a difficult start and unfavorable initial conditions (inexperienced, unfair perceptions) do not necessarily lead to poor performance in the long run. The learning curve effect means that not only are initial conditions important, but learning capacity has a key influence as well (e.g.,

Doz 1996). Therefore, university representatives and inexperienced entrepreneurs should take care to recognize the effects of fairness perceptions on the degree of cooperation and venturing progress. Such perceptions might be improved through the careful management of expectations, communication, and procedural consistency. Furthermore, inexperienced academic entrepreneurs should pursue opportunities to learn and adapt their perceptions; TTO managers similarly should try to provide learning experiences outside the university.

The decreased cooperation (fair–unfair) pattern indicates an experience trap effect (Sengupta et al. 2008). Experienced entrepreneurs think that they have "seen that, done that" and thus may fail to understand the importance of cooperation or have difficulty adapting to new circumstances (Shepherd et al. 2003). Because external changes in the market or industry likely create a need for contractual renegotiations (Ariño and De la Torre 1998, Doz 1996, Reuer et al. 2002), entrepreneurs must be prepared to adapt to changes, without minimizing beneficial cooperation efforts. Those entrepreneurs who terminate their relationship with the university during renegotiations, especially in the context of difficult market circumstances, are more likely to enter a vicious cycle in which their uncooperative behavior is detrimental to venture progress. The failed learning mechanism also might explain Ariño et al.'s (2008) observation that small firms are less likely to change their contracts when collaborative interactions result in governance misalignment. For technology commercialization, experienced entrepreneurs thus should be aware of the trade-off associated with their experience, such that they run the risk of lost flexibility (Dane 2010). Our intervention scenarios note the possibility of halting the vicious circle of decreased cooperation through the early involvement of an extra entrepreneur or multiple experienced team members, but to avoid an even deeper experience trap, those additional members should have experiences that differ from those of the existing team. The collaboration also ultimately includes two parties, so another possible intervention would be to add skilled people to the

TTO staff (Lockett and Wright 2005), which may ensure that entrepreneurs receive enough learning time or help to address market complexity.

Finally, the unsteady cooperation (unfair–unfair) pattern reveals that cooperation and venture progress are likely poor in difficult commercialization settings, featuring inexperienced entrepreneurs who are unable or unwilling to learn. Most entrepreneurship studies are biased toward successful entities, because unsuccessful cases are difficult to sample (Davidsson 2004); our well-supported model shows that in this hypothetical scenario, learning through the commercialization process becomes a vicious cycle, and hindered progress is the outcome. For inexperienced entrepreneurs who want to start commercializing in such conditions, our results are discouraging, because they suggest the project is very likely to fail. Only by involving an experienced entrepreneur early in the process can this unsteady cooperation pattern shift into a positive interaction (Franklin et al. 2001, Mosey and Wright 2007). Although we did not model alternative intervention scenarios in this case, it may help to combine multiple interventions, such as adding skilled TTO staff, changing the business model, and adding team members with specific market knowledge (Van Burg et al. 2008). Furthermore, our sensitivity analyses indicated that a less ambitious planning of the venture could also yield positive results.

Beyond these implications, this study suffers from some limitations that offer recommendations for research. First, our study's empirical data include only a small sample of high-tech companies affiliated with a single university. The external validity of the empirical findings and the model calibration are well supported in this domain but not necessarily beyond it. Second, we used an overall construct of fairness perceptions. Analyzing the dynamics across different dimensions could reveal interesting internal dynamics (Ariño and Ring 2010). Third, the nature of our empirical data does not allow for real-time or close to real-time analyses. The granularity of the events therefore refers to

weeks and months rather than days or hours. Closer observations of commercialization processes and cooperation might reveal more sophisticated patterns (e.g., fair–unfair–fair) and more information to calibrate the model. Fourth, our findings indicate that even experienced entrepreneurs can have difficulties setting up a venture in complex markets. They know how to set up a venture; they just do not have enough knowledge about the complex market they are trying to serve. This finding implies the potential for two types of learning curves: one for learning how to set up a venture, and one for learning how to operate in a complex market. Further research should address the differences in these learning curves and their individual and combined effects on the venture start-up process.

7. Conclusions

This study describes and simulates the commercialization process of a university-owned technology by a new venture. The model outlines the effects of accumulated experience, as well as the results in terms of perception changes and cooperative behavior. We thus contribute to a better understanding of the effects of entrepreneurs' experience and fairness perceptions on their cooperative behavior, opening the "black box" surrounding the role that such perceptions play in technology commercialization processes. If they understand the dynamics associated with this cooperative behavior, managers of technology commercialization and entrepreneurs can gain a better sense of how to ensure effective and cooperative behaviors.

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Figure 1: Cooperation Dynamics Model
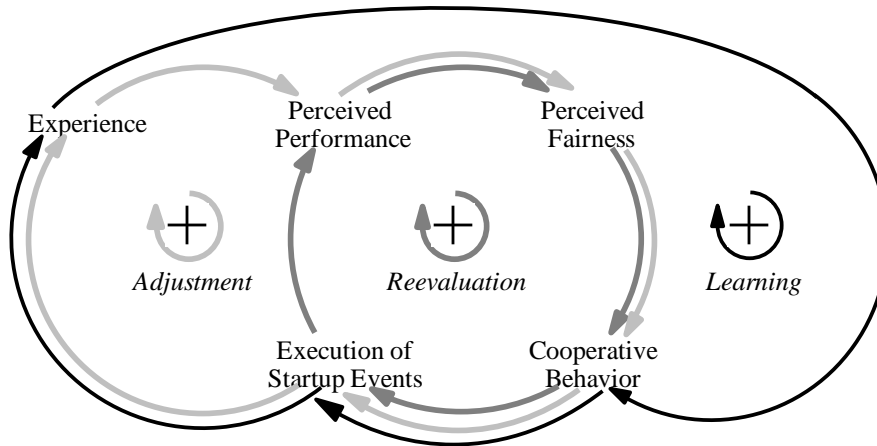
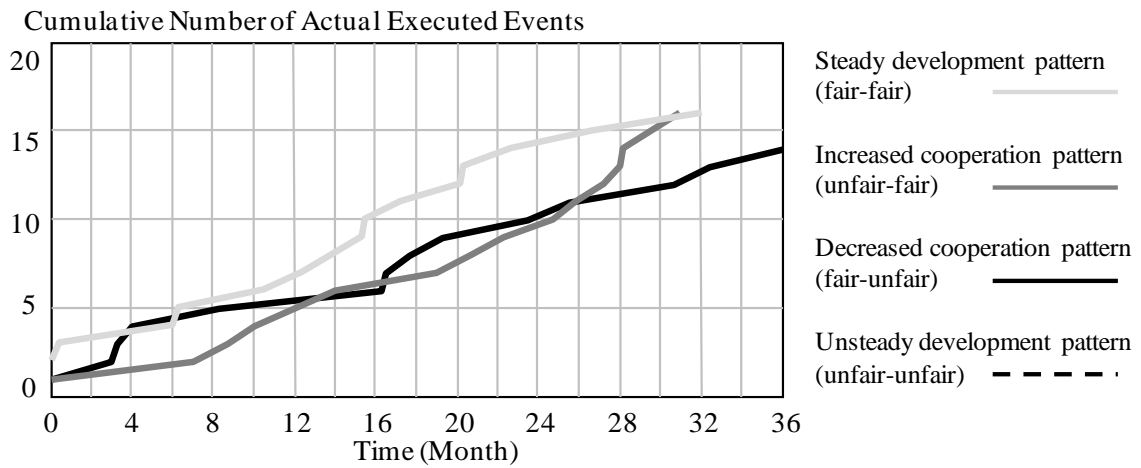**Figure 2: Cumulative Number of Actual Executed Events**
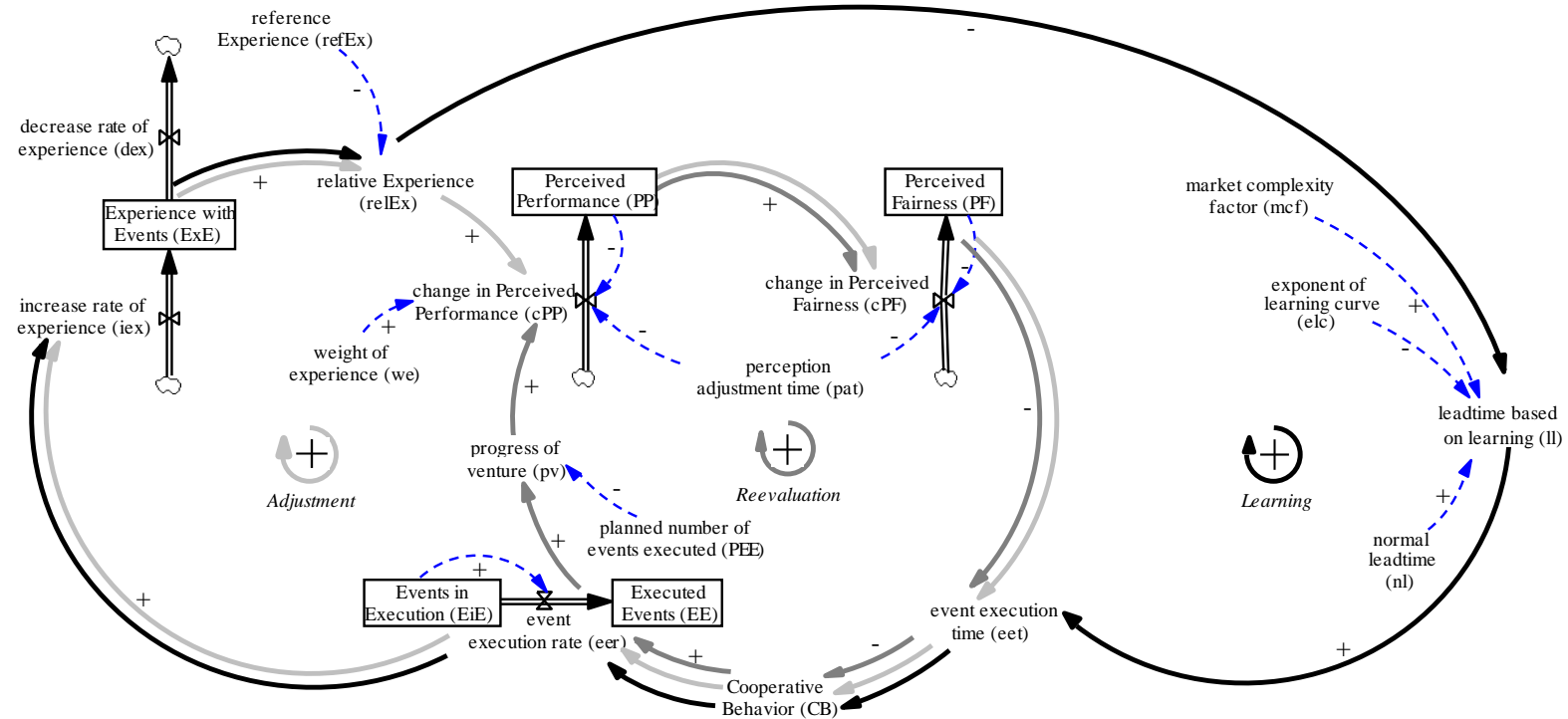
Figure 3: Stylized Model

Figure Legend:

☐ Stock: accumulation that characterizes the state of the system

➤ Flow: rate in which material (or information) flows into or out of a stock

⋈ Valve: regulator of the flow

☁ Source: stock outside model boundary

a ⤍ b Arrow (dashed): causal relationship between an exogenous variable (constant) and an endogenous variable (a leads to b)

b ➤ c Arrow (solid): causal relationship between two endogenous variables (b leads to c)

+ Positive causal relationship: when the cause increases (decreases) the effect will also increase (decrease)
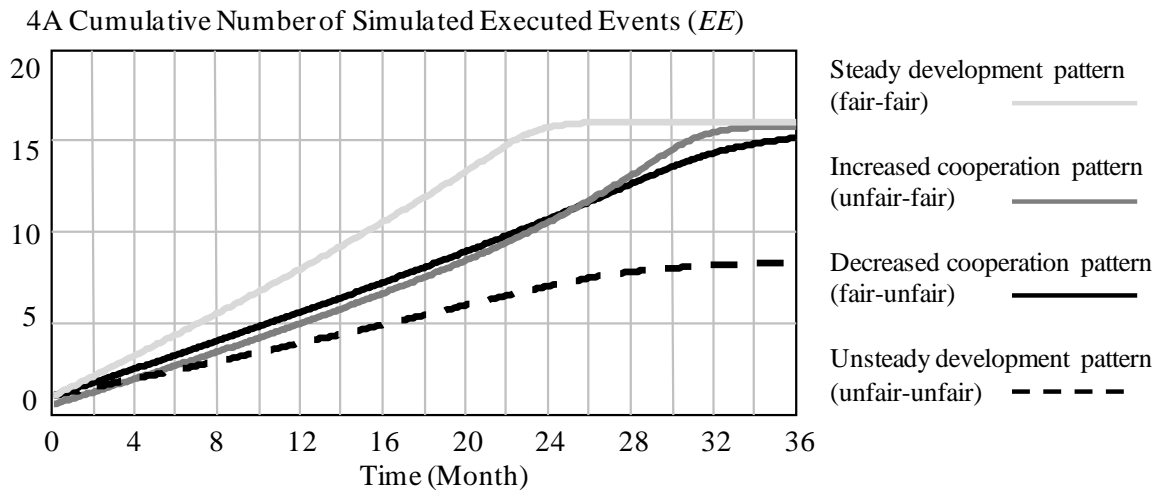
- Negative causal relationship: when the cause increases (decreases) the effect will decrease (increase)

Table 1
Cooperation Patterns

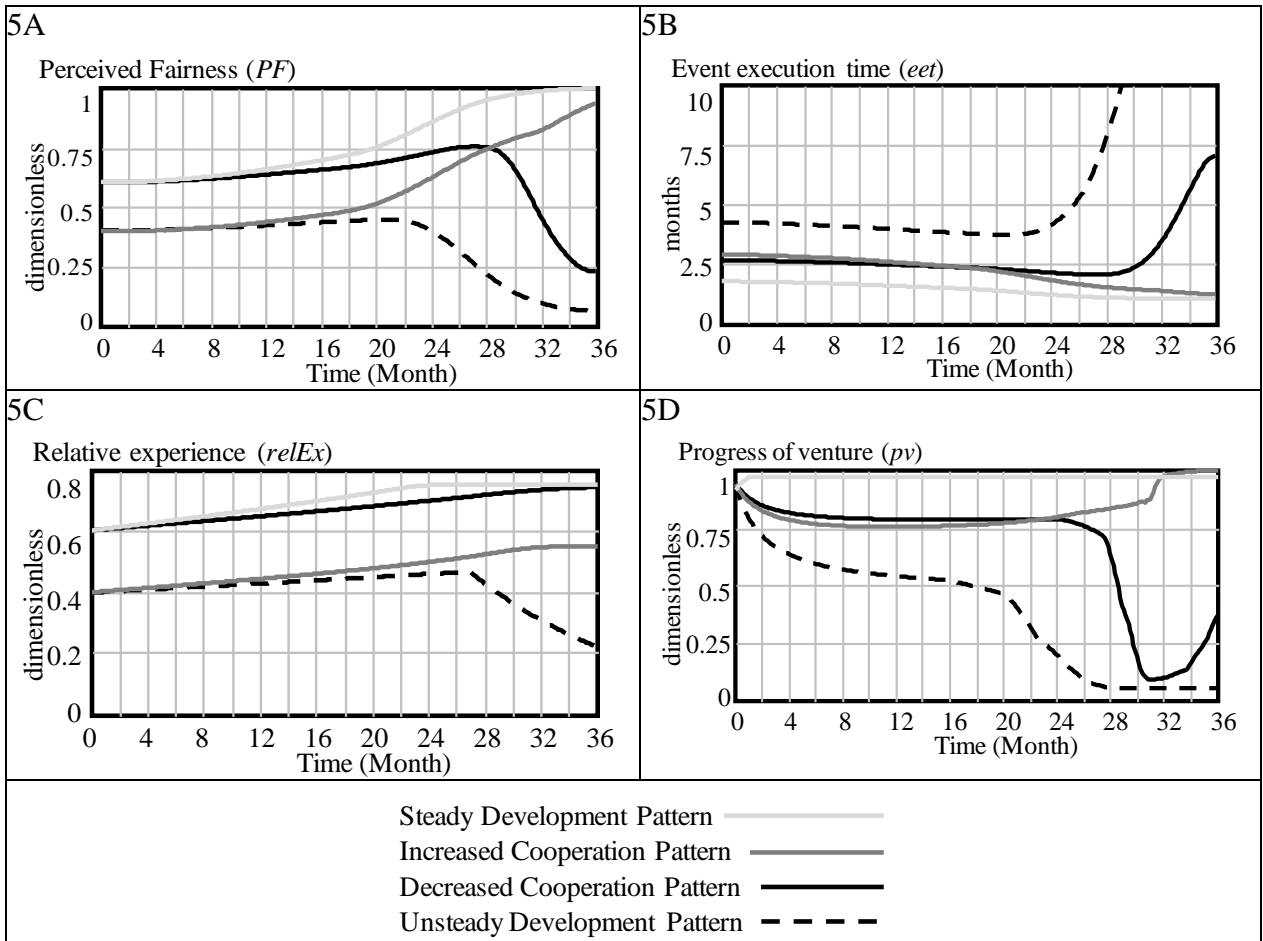|		Initial Experience	
		Low	**High**
Market Complexity	**Low**	*Increased cooperation (unfair–fair)* 6 cases; 1 delayed	*Steady development (fair–fair)* 7 cases; all on time
	High	*Unsteady development (unfair–unfair)* (not empirically observed[1])	*Decreased cooperation (fair–unfair)* 4 cases; 3 delayed

[1]This pattern is not empirically observed but represents a theoretical extrapolation from the findings from the 17 cases (Section 4.2).

Figure 4
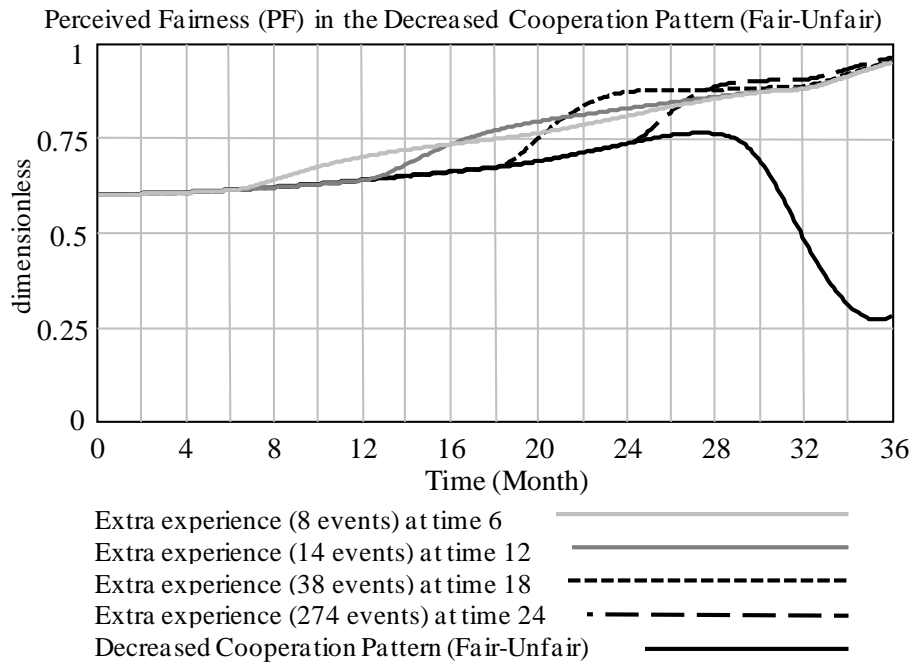**Fit Between Actual and Simulated Executed Events**

4A Cumulative Number of Simulated Executed Events (*EE*)

Steady development pattern
(fair-fair)

Increased cooperation pattern
(unfair-fair)

Decreased cooperation pattern
(fair-unfair)

Unsteady development pattern
(unfair-unfair)

4B	Summary Statistics for Historical Fit		
	Steady Development Pattern	**Increased Cooperation Pattern**	**Decreased Cooperation Pattern**
n	13	14	13
R2	0.9792	0.9818	0.9712
Mean Absolute Percent Error	0.1504	0.1449	0.1185
Root Mean Square Error	0.9000	0.8771	0.9282
Theil's Inequality Statistics			
Bias	0.0621	0.4533	0.0173
Unequal Variation	0.3397	0.0901	0.4336
Unequal Covariation	0.5982	0.4566	0.5491

Figure 5
Dynamic Behavior of Four Cooperation Patterns

5A

Perceived Fairness (*PF*)

5B

Event execution time (*eet*)

5C

Relative experience (*relEx*)

5D

Progress of venture (*pv*)

Steady Development Pattern
Increased Cooperation Pattern
Decreased Cooperation Pattern
Unsteady Development Pattern

Figure 6
From Vicious to Virtuous Cycles
6A. Decreased Cooperation Pattern (Fair–Unfair)

Perceived Fairness (PF) in the Decreased Cooperation Pattern (Fair-Unfair)

Extra experience (8 events) at time 6 ——————
Extra experience (14 events) at time 12 ——————
Extra experience (38 events) at time 18 - - - - - - -
Extra experience (274 events) at time 24 — — — —
Decreased Cooperation Pattern (Fair-Unfair) ——————

6B. Unsteady Development Pattern (Unfair–Unfair)

Perceived Fairness (PF) in the Unsteady Development Pattern (Unfair-Unfair)

Extra experience (43 events) at time 6 ——————
Extra experience (1000 events) at time 12 ——————
Unsteady Development Pattern (Unfair-Unfair) ——————

35
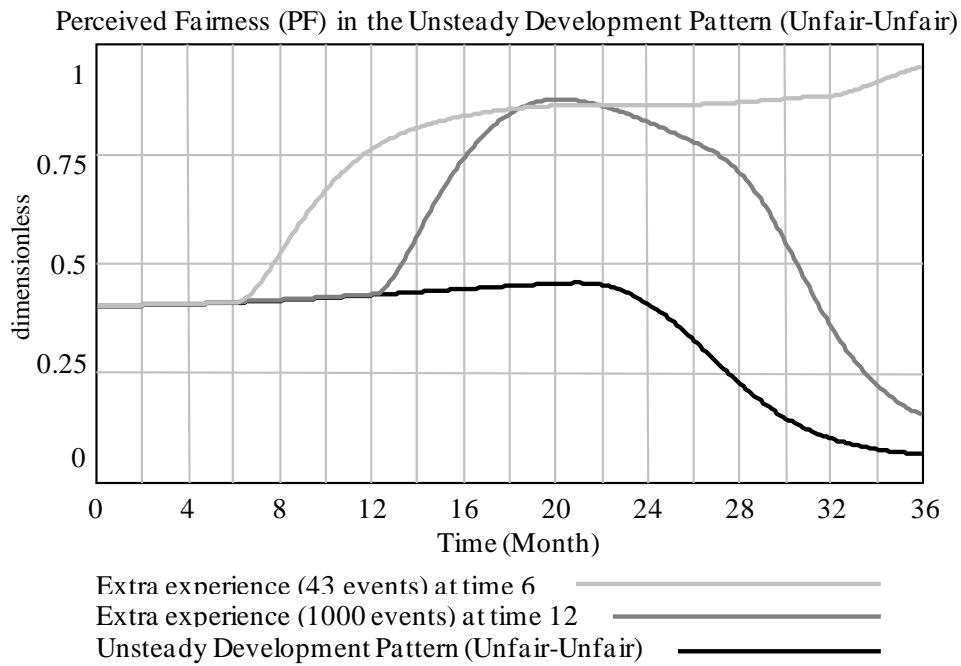
Model documentation accompanying the paper:

Elco van Burg & Kim E. van Oorschot, "Cooperate to Commercialize Technology:
A Dynamic Model of Fairness Perceptions, Experience, and Cooperation",
Production and Operations Management.

1. Introduction

The full simulation model is shown in Figure A. At the core of the model are the three
reinforcing cycles of adjustment, reevaluation, and learning. For clarification reasons we will
explain our model in the reversed sequence, starting with the shortest cycle (the learning cycle,
depicted with the black arrows in Figure A).
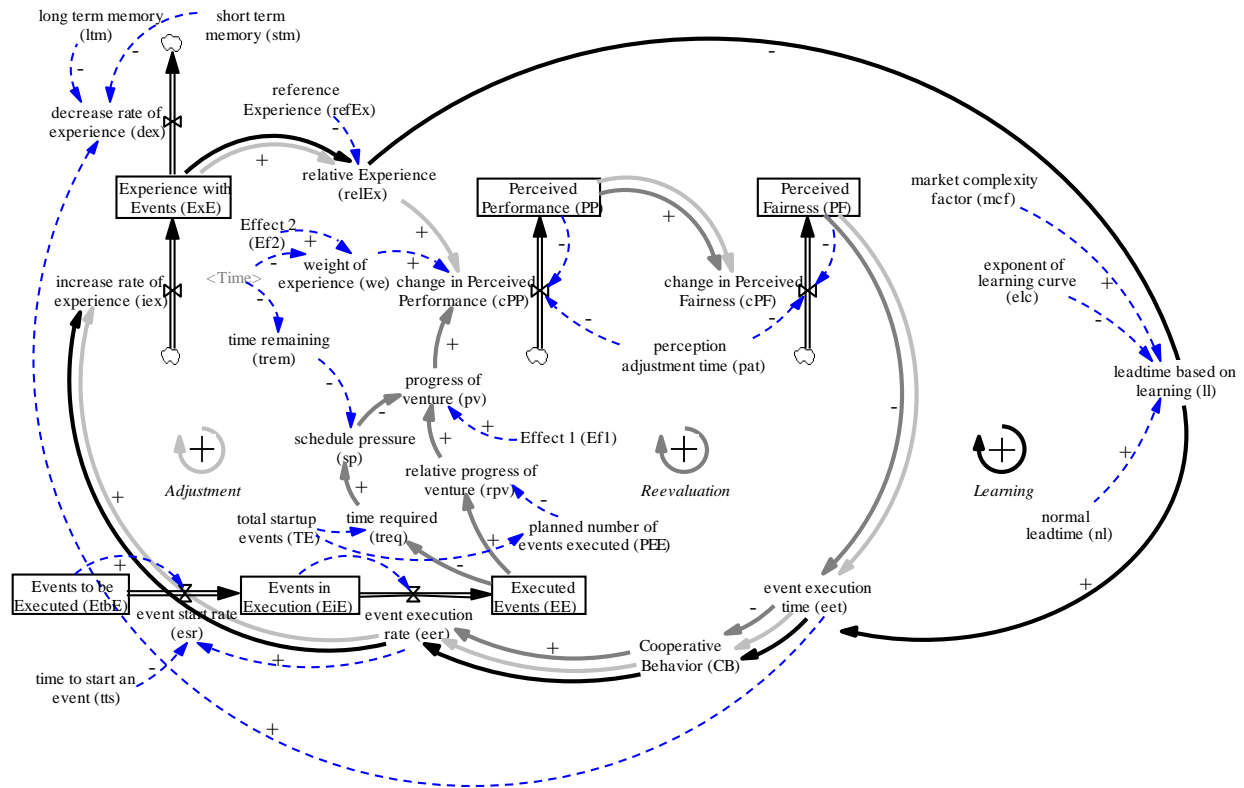
Figure A: Full System Dynamics Model of Fairness Perceptions, Experience, and Cooperation

2. Modeling the Learning Cycle

We start the formalization of the learning cycle at the lower left corner of Figure A: the process
of executing startup and commercialization events. The execution of the 16 most frequent startup
and technology commercialization events (total startup events, *TE,* see equation 1) that were
identified in the process study is represented by three stocks, as shown in Figure A. When the
partners start with an event (event start rate, *esr*), this single event flows from Events to be

Executed (*EtbE*) (equation 2) to the stock of Events in Execution (*EiE*). This *esr* is influenced by the time required to start an event (*tts*) (equation 3 and 4).

$$TE = 16 \tag{1}$$

$$\frac{d}{dt}EtbE = -esr \tag{2}$$

$$esr = \min(\frac{EtbE}{tts}, eer) \tag{3}$$

$$tts = 1 \tag{4}$$

The event execution rate (*eer*) denotes the number of startup events that is executed per month, which is simulated as a flow of events from the stock Events in Execution (*EiE*) to the stock Executed Events (*EE*). As more events are executed, the stock *EiE* is depleted and the stock of *EE* is filled (equation 5 and 6). Every time one event is finished, another one is started (denoted by the arrow from *eer* to *esr*) (see equation 3). The *eer* is determined by the number of startup events in execution (*EiE*) and the degree of cooperative behavior (*CB*) (equation 7). *CB* is linked to the event execution time (*eet*) (equation 8). As such, a shorter *eet* results in more *CB*.

$$\frac{d}{dt}EiE = esr - eer \tag{5}$$

$$\frac{d}{dt}EE = eer \tag{6}$$

$$eer = EiE \cdot CB \tag{7}$$

$$CB = \frac{1}{eet} \tag{8}$$

Initially (at *t* = 0), 14 out of the 16 events are in the stock of Events to be Executed (*EtbE*) (equation 9), and the stocks *EiE* and *EE* both contain only one event. For *EE* this is the actual invention to be commercialized (equation 11), for *EiE* this is the next event (following the invention) both partners are jointly working on (equation 10).

$$EtbE(0)= TE\text{-}EiE(0)\text{-}EE(0) \tag{9}$$

$$EiE(0) = 1 \tag{10}$$

$$EE(0) = 1 \tag{11}$$

Note that the total number of startup events (*TE*) eventually limits the event execution rate. Because *TE* is 16, no more than 16 events can be executed. When 16 events are executed (*EE* = 16), the venture process is finished. Therefore, *EE* can never rise above 16, and for successful ventures, graphs of EE showing the behavior over time will always flatten after 16 events have been executed.

Every event that is executed increases the accumulated experience of the entrepreneur. Therefore, the *eer* directly influences the increase rate of experience (*iex*) (equation 12).

Experience might decrease though if the entrepreneur starts to forget past events (*dex*). This situation occurs when the time between events is very long. Then, the events that happened a long time ago are not part of the working memory of the entrepreneur (short-term memory, *stm*) and the information needs to be recalled, repeated, re-discussed, and so on, which increases the time required for the next event. As long as the time between events is shorter than the *stm*, there is no forgetting. When the time between events is longer than the *stm*, the entrepreneur starts to forget some of his/her previous experiences. The rate at which the experience decreases is defined by the long-term memory (*ltm*) (equation 13).

$$\frac{d}{dt} ExE = iex - dex = eer - dex \tag{12}$$

$$dex = \text{IF } (eet > stm) \text{ THEN } (ExE/ltm) \text{ ELSE } (0) \tag{13}$$

$$stm = 6 \tag{14}$$

$$ltm = 12 \tag{15}$$

To determine the relative experience of an entrepreneur compared to other entrepreneurs (*relEx*), we consider the ratio of *ExE* and the reference experience (*refEx*) (equation 16), which indicates the maximum level of experience the entrepreneur can attain in this industry (equation 17). As such, *relEx* is expressed as a number between 0 and 1, such that 0 indicates being highly inexperienced and 1 is highly experienced.

$$relEx = \frac{ExE}{refEx} \tag{16}$$

$$refEx = 100 \tag{17}$$

Finally, we define an initial value of *ExE* according to the relative experience of the entrepreneur at the start of new venture process (*relEx*(0), see equation 18). We distinguish two situations: the entrepreneur is initially inexperienced or the entrepreneur is initially experienced:

$$ExE(0) = relEx(0) \cdot refEx \tag{18}$$

$$relEx(0) = 0.4 \text{ (for an inexperienced entrepreneur)} \tag{19}$$

$$relEx(0) = 0.6 \text{ (for an experienced entrepreneur)}` \tag{20}$$

Higher *relEx* results in decreased event execution time, via the learning curve (equation 21). Learning curve theory posits that productivity rises by a given percentage with each doubling of the level of experience (Sterman 2000: 507, see also Lapré et al. 2000, Wiersma 2007). The productivity increase through this learning curve is defined as leadtime based on learning (*ll*):

$$ll = mcf \cdot nl \cdot relEx^{elc} \tag{21}$$

$$nl = 2 \tag{22}$$

$$elc = -0.15 \tag{23}$$

where normal leadtime (*nl*) is the shortest leadtime that can be attained at the reference experience level in a very complex market. Reductions of, in this case leadtimes, of 10% to 30% per doubling of cumulative experience have been documented in various industries (Sterman

2000). Because we do not model a process with highly repetitive activities, we assume that reductions in our case fall at the lower end of the spectrum, or 10%. For every doubling of *ExE*, the *ll* declines by approximately 10%. This 10% reduction corresponds with a value of the exponent of the learning curve (*elc*) of -0.15 (equation 23). The *elc* is a constant that describes the strength of the learning curve. Because the exponent of the learning curve (*elc*) is negative, higher *relEx* implies a shorter leadtime based on learning (*ll*). Figure B shows the relationship between *ExE* and *ll*, in which the 10% reduction is realized when the exponent of the learning curve (*elc*) is -0.15.
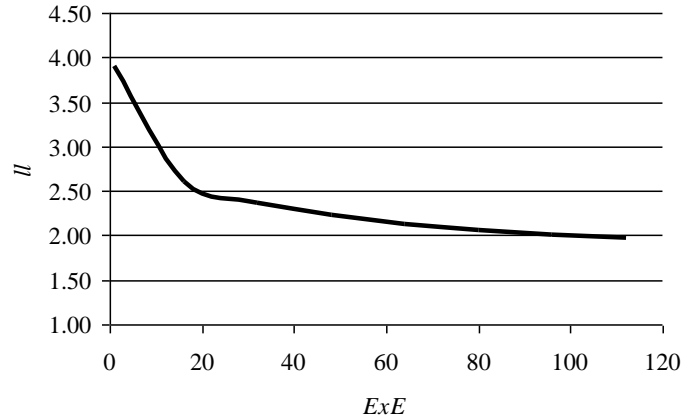
Figure B: Leadtime based on learning (ll) as a function of Experience (ExE)

In addition to experience, *ll* is also positively influenced by a constant, the market complexity factor (*mcf*). This *mcf* defines the complexity level of the market in which the new venture will operate. The lower the *mcf* the 'easier' (e.g., in terms of high predictability, low diversity, low volatility, etc.) the market is. Thus, at the same level of experience, *ll* is longer in complex markets as opposed to easier markets. Two situations are distinguished here: a situation in which market complexity is low and one in which market complexity is high:

$$mcf = 0.50 \text{ (for a low market complexity)} \tag{24}$$

$$mcf = 0.75 \text{ (for a high market complexity)} \tag{25}$$

Besides the learning effect, the time needed to execute an event (*eet*), is also affected by the perceived fairness (*PF*) of the entrepreneur.

$$eet = ll / PF . \tag{26}$$

This equation shows that higher perceived fairness (*PF*) shortens the time needed to execute an event (*eet*). Subsequently, the *eet* feeds back into the cooperative behavior (*CB*), which closes the learning cycle (see equation 8).

3. Modeling the Reevaluation Cycle

The reevaluation cycle is depicted with the dark grey arrows in Figure A. The number of executed startup events (*EE*) allows the entrepreneur to perceive the progress of the venture (*pv*),

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which changes the perceived performance of the venture (*PP*). Because changes in perception take some time, it is modeled as an adaptive expectation that gradually adjusts to the actual value of the variable (Sterman 2000), via the change in Perceived Performance (*cPP*) (equation 27). The actual value of the variable is determined by *pv*. In the beginning, however, it is difficult for the entrepreneur to adequately assess venture performance based on the small number of executed events. When the entrepreneur is experienced, he or she should be more optimistic about the performance of the venture ("I have done this before, I know what I am doing, and I will be successful"), which indicates a higher *PP*. When the entrepreneur is inexperienced, the performance likely seems low in the beginning ("I don't know how this works, I don't know if I am doing this right, and maybe others are much better at this"). Therefore, we assume that in the beginning, performance depends on *relEx*, but after more events get executed, *PP* is influenced more by *pv*. This shift in impact is determined by the weight of experience (*we*). This *we* is defined as a non-linear decreasing function (Effect 2, *Ef2*) of time (*t*), starting at 1 and decreasing to 0 (see equation 29 and 30). The time required to adjust the *PP* (the perception) to the actual value (determined by *pv*, *relEx*, and *we)* is determined by the perception adjustment time (*pat*), which is equal to 2 months (equation 31):

$$\frac{d}{dt}PP = cPP = \frac{-PP + (we \cdot relEx + (1-we) \cdot pv)}{pat} \tag{27}$$

$$PP(0) = we \cdot relEx + (1-we) \cdot pv \tag{28}$$

$$we = Ef2(t) \tag{29}$$

$$Ef2 > 0, \ Ef2' < 0, \ Ef2'' < 0, \ Ef2(0)=1, \ Ef2(7)=0.98, \ Ef2(22)=0.32, \ Ef2(32)=0 \tag{30}$$

$$pat = 2 \tag{31}$$

The influence of *relEx* on *PP* decreases over time (because *we* decreases) and after month 20, *pv* is the most dominant factor to determine *PP*. In terms of our causal loops, this means that in the beginning the adjustment-loop (with *relEx*) and the learning-loop are the drivers of system behavior. Over time, the influence of *relEx* decreases (because *we* decreases), causing the reevaluation (with *pv*) and the learning-loop to determine the model behavior.

The progress of the venture (*pv*) is determined by the relative progress (*rpv*) and schedule pressure (*sp*) (equation 32). The *rpv* is the number of events that are actually executed (*EE*) compared to the number of events that are expected to be executed, based on the time that has elapsed (*t*) and the expected leadtime of each event (*el*) (see equation 33).

$$pv = rpv \cdot Ef1(sp) \tag{32}$$

$$rpv_t = \frac{\text{actual number of events executed } (EE_t)}{\text{planned number of events executed } (PEE_t)} = \frac{EE}{\min(TE, t/el + EE(0))} \tag{33}$$

This equation shows that *EE* is positively related to *rpv*. The more events are executed (higher *EE*), the higher the relative progress of a venture (*rpv*). However, because time (*t*) is in the denominator of the equation, the elapsed time has a negative effect on the *rpv*. The more time has elapsed, the higher the value of *t,* which can potentially reduce *rpv*. When the actual progress cannot keep up with the planned progress, *rpv* can decrease if *EE* is not increasing sufficiently.

Schedule pressure (*sp*) is defined as the ratio of time required to execute all remaining events and the time remaining to do all these events (equation 34). Schedule pressure (*sp*) affects *pv* through the function Effect 1 (*Ef*1). *Ef*1 is modeled as a non-linear decreasing function of *sp*. When, for example, 75% of the events have been executed (*rpv* = 0.75) in almost 100% of the planned time, there is significant schedule pressure to finish the last 25% of the events on time. Because of this high schedule pressure, the perceived progress of the venture (*pv*) is much lower than the 75%, which is determined by *Ef*1 (equation 35). As such, *sp* behaves as a multiplier. When events are executed according to plan (or even ahead of plan), *sp* ≤ 1, and the *Ef*1*(sp)* = 1. When the number of executed events is lower than planned, *sp* will be larger than 1, and *Ef*1 will be lower than 1, thereby decreasing the perceived progress of the venture. Because *sp* is a multiplier, it can strengthen the negative effect of *rpv*, but it will not make a negative effect of *rpv* positive.

$$ sp = \frac{\text{time required}}{\text{time remaining}} = \frac{(TE - EE) \cdot el}{TE \cdot el - t} \tag{34} $$

$$ Ef1 > 0, \; Ef1' < 0, \; Ef1'' < 0, \; Ef1(0)=1, \; Ef1(1)=1, \; Ef1(2)=0.5, \; Ef1(5)=0.1 \tag{35} $$

PP directly influences the perceived fairness (*PF*) (equation 36). *PF* is also modeled as an adaptive expectation: it takes some time before the entrepreneur internalizes the performance, so *PF* lags *PP* by a certain time (*pat*):

$$ cPF = \frac{d}{dt} PF = \frac{-PF + PP}{pat}. \tag{36} $$

We assume that *PF* can be quantified as a number between 0 and 1, in which 0 indicates that the entrepreneur perceives total unfairness and 1 denotes high fairness perception. The initial *PF* (*PF*(0)) is determined by the initial relative experience (*relEx*(0)), which is also expressed as a number between 0 and 1.

$$ PF(0) = relEx(0) = 0.4 \text{ (for an inexperienced entrepreneur)} \tag{37} $$

$$ PF(0) = relEx(0) = 0.6 \text{ (for an experienced entrepreneur)} $$

Thus, based on the empirical observations, we model that an inexperienced entrepreneur begins the venture processes with a relatively low perceived fairness, and an experienced entrepreneur will start these processes with a relatively high perceived fairness.

The reevaluation cycle continues from *PF* to *eet*, *CB*, *eer*, *EE*, *pv*, and *cPP*. Because these relationships have been described already, it suffices here to refer to respectively equations 26, 8, 7, 6, 32, and 27.

4. Modeling the Adjustment Cycle

The adjustment cycle is reflected by the light grey arrows in Figure A. Starting at the execution of events, the cycle continues with experience increase, perceived performance, perceived fairness, event execution time, and the cycle closes with the impact of cooperative behavior on

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the event execution rate. Because all of these relationships have been defined in the previous sections, we limit ourselves here to referring to the equations described in Section 2 and 3.

5. Sensitivity Analyses

Our fourth pattern, the unsteady development pattern (unfair-unfair) was not validated by our case study (due to a lack of empirical observations of this pattern), but appeared as a logical possibility during our simulations. To analyze the sensitivity of this pattern to values of the exogeneous variables, we have done two sensitivity analyses:
1) changing the expected leadtime, which determines the planned number of events executed;
2) changing the weight of experience, which determines when the dominance of the adjustment-loop switches over to the reevaluation-loop.

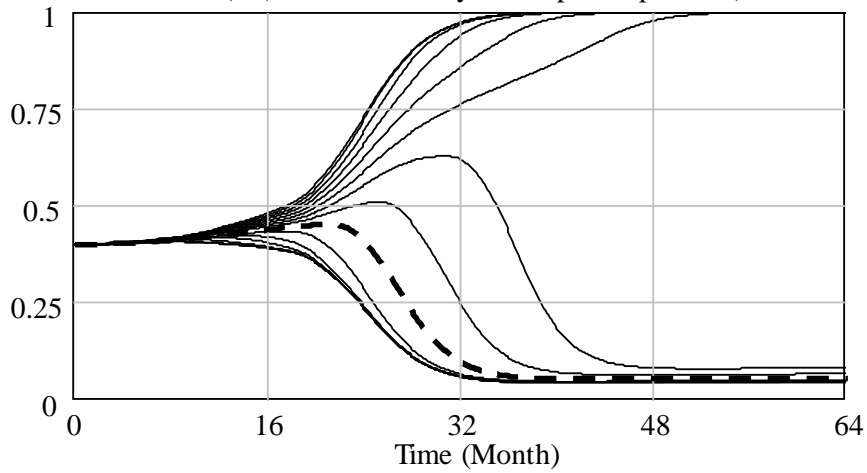### *5.1 Sensitivity analysis of expected leadtime (el)*
As we explained earlier, the progress of the venture is determined by the expected leadtime, the lead time that the entrepreneur perceives as normal. Based on this leadtime, the entrepreneur determines or plans what a normal venture progress is. When progress keeps up with this plan, the progress of the venture is good (not decreasing), when progress falls behind this plan, progress is perceived as bad (decreasing). Obviously, if the plan is less ambitious (e.g., if the entrepreneur expects that it takes longer than 2 months to execute an event), we would expect more ventures in a complex market to succeed, just because the entrepreneur still perceives the performance as increasing (which has a positive influence on perceived fairness and cooperation through the reevaluation loop). On the other hand, if the plan is more ambitious (e.g., if the entrepreneur expects that it takes less than 2 months to execute an event) we would expect less ventures to succeed, because the entrepreneur perceives the performance as decreasing (which has a negative influence on perceived fairness and cooperation through the reevaluation loop). Therefore, we have varied the value of the expected leadtime from 0.25 to 4 months (with steps of 0.25) to see how this influences the results. We have depicted the effects of varying the expected leadtime on the number of executed events (*EE*), perceived fairness (*PF*) and relative progress of the venture (*rpv*) in Figure C. The dotted lines in Figure C denote the original pattern (in which the expected leadtime is 2 months).

Figure C shows that indeed, with less ambitious planning (longer expected leadtimes) the vicious cycles in the unsteady development pattern can be turned around into virtuous cycles. If the expected leadtime is at least 2.75 months (38% longer than in the original pattern), the low relative progress of the venture in the beginning will be defeated and later, sufficient progress will be made to catch up on the initial delays. If the expected leadtime is shorter than 2.75 months, the initial unfair situation may improve a little in the beginning, but it will decrease and become even more unfair in the end. In other words, our modeled system is sensitive to changes in the expected leadtime. However, the expected leadtime has to increase with 38% compared to the case-based leadtime values before the behavior of the unsteady development pattern fundamentally changes (before unfair-unfair becomes unfair-fair). So, a venture process that in the original pattern was planned to take 32 months (16 events, 2 months per event), would have to be replanned to 44 months (+38%) to change the unfair process to a fair process. Because this is a rather large step (adding one year to a 2.67 year-plan), we believe that the unsteady development pattern is modeled in a realistic way.

Executed Events (EE) in the Unsteady development pattern (unfair-unfair)
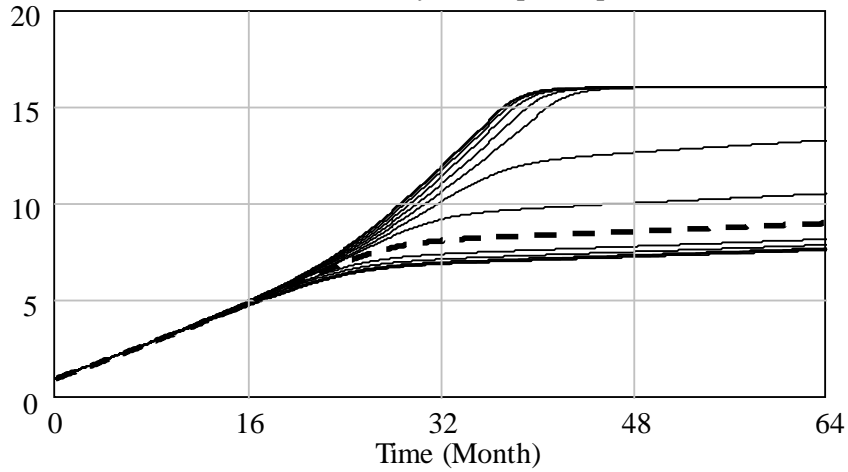
Perceived Fairness (PF) in the Unsteady development pattern (unfair-unfair)

Relative progress of venture (rpv) in the Unsteady development pattern (unfair-unfair)
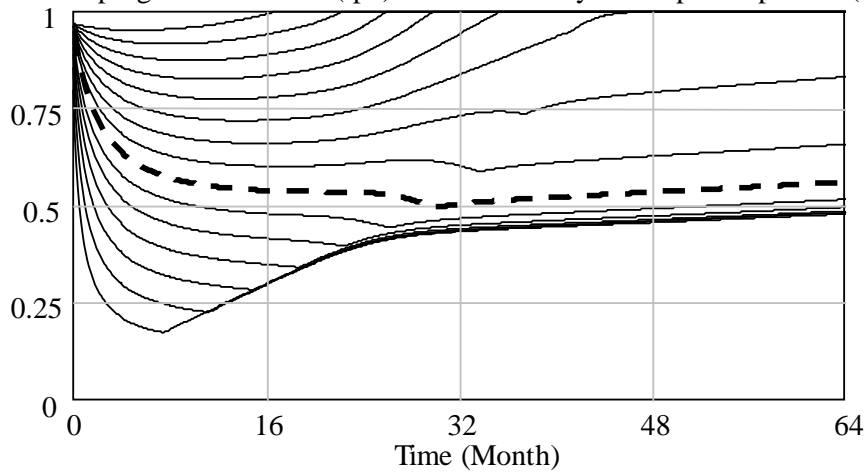

Figure C: Sensitivity analysis of expected leadtime (el). The graphs on top of each figure reflect the situation in which el = 4 months, the lowest graph reflects the situation in which el = 0.5 months

5.2 Sensitivity analysis of weight of experience (we)

As we have explained earlier, the weight of experience determines to what extent the Perceived Performance (*PP*) is determined by the relative experience of the entrepreneur (*relEx*) and by the progress of the venture (*pv*) (equation 28):

$$PP = we \cdot relEx + (1 - we) \cdot pv$$

Based on our case study material, *we* is defined as a non-linear decreasing function (*Ef2*) of time (*t*), starting at 1 and decreasing to 0, as shown in Figure D.
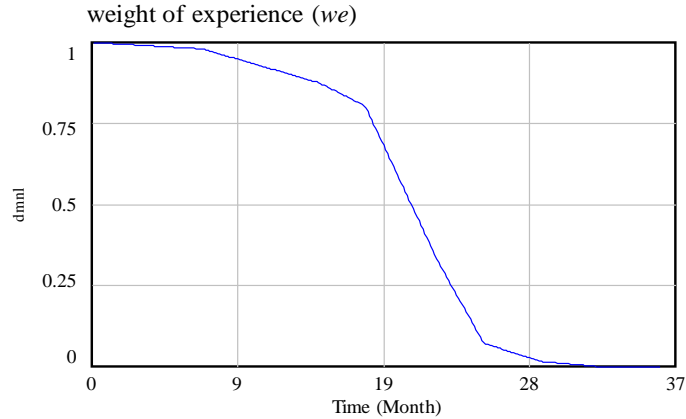

Figure D: Weight of experience as a non-linear decreasing function of time

Changing the shape of this function changes the way PP is determined, and as a result it may change the unsteady development pattern. Therefore we also have performed a sensitivity analysis of *we*. Obviously, there are many ways to change the curve of Figure D. It can be shifted to the left or right, squeezed, flipped horizontally and vertically, et cetera. In order to limit the multitude of options we decided to change the weight of experience curve into a linear curve and to let the curve shift from being monotonic decreasing to monotonic increasing, to get a good impression of the influence of the values of *we* on the simulation results (note that this also includes the possibility of having a constant value of 0.5). Figure E shows the different values we have used in this sensitivity analysis. The sensitivity results are shown in Figure F.
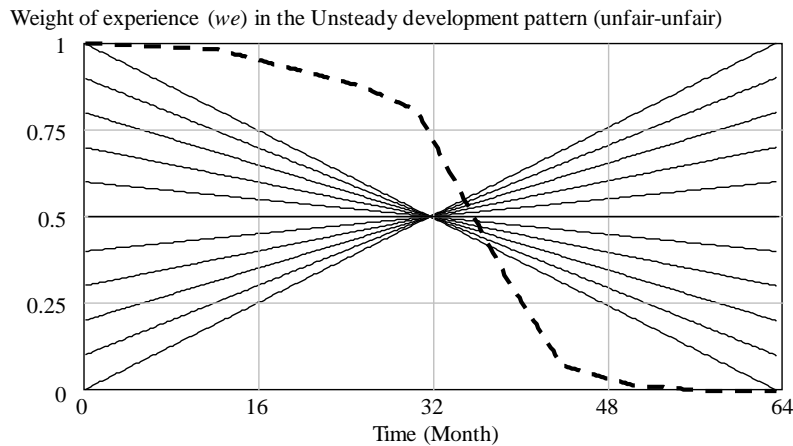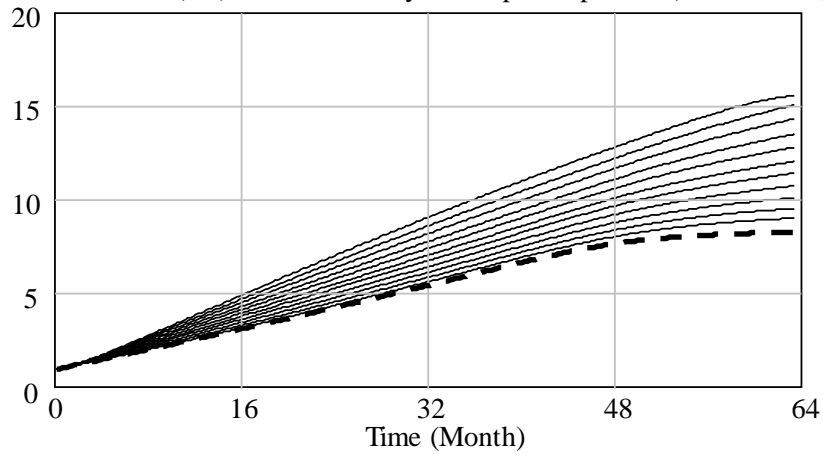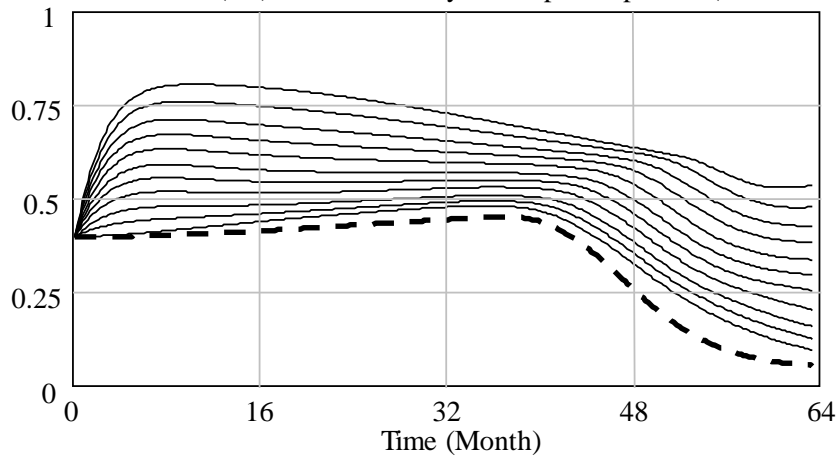

Figure E: Different weights used in the sensitivity analysis (the original weight is showed with a dashed line)

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Executed Events (*EE*) in the Unsteady development pattern (unfair-unfair)

Perceived Fairness (*PF*) in the Unsteady development pattern (unfair-unfair)

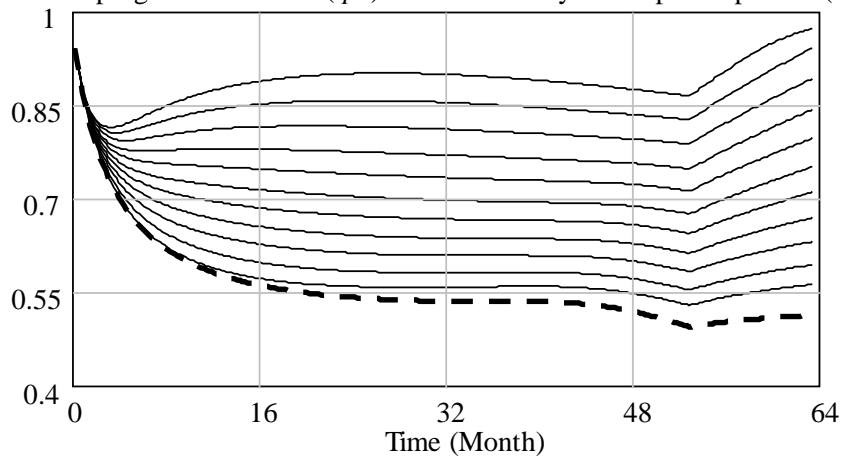Relative progress of venture (*rpv*) in the Unsteady development pattern (unfair-unfair)

Figure F: Sensitivity analysis of weight of experience (we). The graphs on top of each figure reflect the situation in which we *is low in the beginning and high in the end.*

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Figure F shows that if experience is given a different weight in determining *PP*, it can influence the unsteady development pattern in such a way that the unfair perceptions turn into almost stable fair perceptions. These are the situations in which the weight of experience is extremely low in the beginning and extremely high in the end. As Figure F shows, there is one situation in which the unsteady development pattern (unfair-unfair) ends with fair perceptions and in which all 16 events are executed, and one situation in which this pattern ends with almost fair perceptions (close to 0.5) and in which 15 events got executed. These two situations have a weight of experience in the beginning of respectively 0 and 0.1 (and consequently in the end the weight is 1 and 0.9). These results do not suggest that it is better to have no experience in the beginning, but that it would be better not to take this experience into account when assessing the performance of the venture. However, it seems hard or even almost impossible to change the subconscious cognitive effects of past experiences, in particular the effect of successful experiences (Burmeister and Schade 2007, Ucbasaran et al. 2003, Busenitz and Barney 1997). Therefore we believe that the unsteady development pattern is robust to changes in the weight of experience and that this pattern could be a realistic pattern.

What we can learn from the two sensitivity analyses is that if there is a way to turn the unfair-unfair situation around, it is by less ambitious planning and by ignoring previous experience when assessing the preliminary performance in a new venture. It is as if the entrepreneur should start with a clean sheet, no plans, no expectations. In theory, if the stock of experiences in the human mind could be 'emptied' this could work, but it also has the danger of never-ending ventures that do not fail, but also never get anywhere.

6. Exogenous Variables

An overview of the values of all these exogenous variables appears in Table 1.

Table 1
Values of Exogenous Variables

Variable	Description	Value	Units
TE	Total startup events	16	events
tts	Time to start an event	1	month
EiE(0)	Initial events in execution	1	event
EE(0)	Initial executed events	1	event
stm	Short-term memory	6	months
ltm	Long-term memory	12	months
refEx	Reference experience	100	events
relEx	Relative experience	0.4 or 0.6*	dimensionless
el	Expected leadtime	2	months
nl	Normal leadtime	2	months
elc	Exponent learning curve	-0.15	dimensionless
mcf	Market complexity factor	0.5 or 0.75**	dimensionless
pat	Perception adjustment time	2	months

* 0.4 for an inexperienced entrepreneur, 0.6 for an experienced entrepreneur.
** 0.5 for a low complexity market, 0.75 for a high complexity market.

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