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The Emergence of Disruption

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The Emergence of Disruption

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Abstract

We study the influence of technological efficiency and organizational inertia on the emergence of competition when firms decide myopically. Using an agent-based computer simulation model, we observe the competitive reaction of a former monopolist to the advent of a new competitor. While the entrant uses a new technology, the monopolist is free either to stick to his former technology or to switch to the new one. We find that—irrespective of details regarding the demand side—a change of industry leadership occurs only if the new ("disruptive") technology is not too efficient and organizations are inert.

Keywords: strategic management, organizational decision making, disruptive technologies, agent-based simulations

1 Introduction

Based on extensive long-term studies of the disk drive and other industries, Christensen introduced the concept of "disruptive technology" ([4]). According to Christensen, initially such a technology is employed in a novel market segment and, when judged according to the features most relevant to the incumbents' current customers, it is inferior to the technology used by the incumbents in the established market segment. Nevertheless, over time the firms using the disruptive technology are able to successfully invade the established market segment from the lower end of the market and industry leadership changes. Christensen's finding provides empirical support to the resource-based and organizational learning perspective of the theory of the firm, whereas other approaches in general predict advantages for incumbents due to learning by doing, economies of scale and scope, network economies of scale, etc. (see, e.g., [7], [11], [9]).

Table 1 provides an example of a disruptive technology: 5,25 inch disk drives were used in the early eighties' desktop computers and, initially, were inferior to the 8 inch drives used in minicomputers in terms of capacity, access time and cost/MB—the features most relevant to a minicomputer user. However,

Feature	8 Inch Drives (Minicomputer)	5,25 Inch Drives (Desktop Computer)
capacity (MB)	60	10
peripheral volume (inch^3)	566	150
weight (pounds)	21	6
access time (ms)	30	160
cost/MB ($)	50	200
unit cost ($)	3000	2000

Table 1: Disruptive Technology 5,25 Inch Drives ([4], p.15)

by 1986 industry leadership changed from CDC, the leading 8 inch vendor, to the new entrant Seagate, and most of the firms that were producing 8 inch drives vanished (see [2], p. 543). Christensen also demonstrates that it is the incumbents who are leading in “sustaining technologies”, i.e. innovations that follow the current trajectory of technological improvement, and are trying to find new technical solutions to tackle the flattening of the current technology’s S-curve. Thus, technological (in)competency cannot explain the failure of industry leaders, but this is rather done by factors rooted in the way new product development projects are valued. Empirical evidence suggests the following causes for disruption:

- *Market Segment Overlap*
  Disruption can only occur if different segments have basically the same needs with different feature weights, though. As shown in Table 1, lower system price can compensate for inferior product features and learning by firms must be faster than the adaption of the customers’ needs, allowing entrants to follow the new, disruptive trajectory of improvement to catch up with the incumbents from below (see [3]).
- *Incentives*
  If an incumbent considers switching to the new technological trajectory of a disruptive technology early, he has to deal with the fact that important current customers are given up for highly insecure new markets which, initially, are too small to support the growth rate of the incumbent’s current organization and given the current organizational design offer lower margins (see [3]).
- *Organizational Inertia*
  An organizational design is adapted to the needs of the firm’s customers (see, e.g., [5]) and frames the way the environment is seen and how problems are solved. This makes radical change hard and time-consuming. Also, an integrated firm is conflict-ridden and hard to manage if the degree of commonality (economies of scope) is low. Henderson and Clark [6], for instance, show that incumbents often fail when confronted with architectural innovations rather than with the introduction of new components, as in such a case the internal distribution of labor and communication channels have to change. Frequently, disruptive technologies entail new architectures based on standard, off-the-shelf components (see [4]). Similarly, Tushman and Anderson show that in the minicomputer and airline industries competence-destroying innovations were made by new firms, while competence-enhancing ones were made by incumbents ([12]).

Given these empirical findings, Christensen suggests that disruptive technologies can best be tackled by continuous monitoring of potentially overlapping market segments, long-term projections of technological trajectories and, to provide the appropriate learning environment, the setup of a completely separated, independent new organization in the market segment from where disruption is expected.

Several authors have developed formal models to study disruption: Adner ([1]) formulates a market-driven model to analyze market conditions under which disruption occurs. Adner introduces the concepts of preference symmetry and preference overlap to characterize the relationship between preferences of different market segments. Using an agent-based computer simulation with myopic firms, he identifies different competitive regimes: convergence, isolation, and disruption. Focusing on the market conditions under which these regimes arise, Adner uses a simplified technological model: firms can move freely to reach any position within a certain distance, i.e., there are no specified technological trajectories in his model (for a similar "history-friendly" model of the computer industry, see [8]).

Nault & Vandenbosch [10] identify conditions under which an entrant is able to outperform an incumbent in a rational, game-theoretic setting. They view disruptive technologies as technologies leading to a next-generation product with a greater market response and, therefore, higher cash flows. They define capability advantages as lower launching costs for the next-generation product. Under the condition that the entrant has a capability advantage in a disruptive technology, he is able to outperform the incumbent even though both technologies are available to both firms at the same time and both players are perfectly rational.

This article endeavors to add another important aspect to the explanation of the emergence of competition: using rational, myopically optimizing firms, we study the influence of organizational inertia and technological efficiency on the emergence of competition between an incumbent and an entrant using a new technology. This new technology is characterized by its efficiency and is also available to the incumbent. While technological efficiency determines the speed of improvement offered by a technology per se, organizational inertia determines the speed at which an organization can be adapted so as to actually reach a desired product position. We thus endogenize the cost differences exogenous to the Nault & Vandenbosch model and characterize each technology via a simplified S-curve model. Using an agent-based simulation, we study the effect of technological efficiency under various market conditions and organizational structures and identify four competitive scenarios: entrant failure, diverse and duopolistic competition, and disruption. These competitive scenarios show robustness for all parameter combinations other than technological efficiency and organizational inertia.

The remainder of this article is organized as follows: in the next section, we present our model of technologies, describe the market structure and consumers' behavior and define the firms' decision-making process (agent design). On this basis, the third section presents the structure of the agent-based simulation and the experimental design. In the results section, we look at the outcome of our experiments. In the final section, we draw conclusions and discuss the managerial implications of our findings.

2 Model

Our model consists of 3 components: technology, market and a firm's decision. The technology part connects product performance (features) to a firm's investment, i.e. the movement of the product position in the feature space as a function of the investment of the firm. The market describes the consumers' choice, their preferences and market dynamics. In the firm's decision part, we describe the firm's objective function and decision-making process. In the following, let i, j, k, l denote indices of consumers, firms, technologies, and features, respectively.

Technology:

A technology α_k is a vector that specifies a linear trajectory of possible product positions in a two-dimensional feature space that are reachable through investments in product development over time:

$$\alpha_k = \lambda_k(\sin\delta_k, \cos\delta_k), \tag{1}$$

where $\delta_k \in (0, \pi/2)$ describes the direction (feature mix), and $\lambda_k > 0$ the efficiency of the technology, i.e. the larger λ_k, the higher the feature levels of a product for a given investment sum.

There are two technologies available: at first, only α_1 used by the incumbent is available. α_2 is the (potentially) disruptive technology and the only choice available to the entrant. By the time of entry τ, the incumbent firm is free to choose either of the two technologies. Let us denote technology choice by index variables $c_{j,t} \in \{0, 1, 2\}$, where $c_{1,t} = 1, t < \tau$ for the incumbent and $c_{2,t} = 2, t \geq \tau$ for the entrant. A zero choice indicates absence of a firm from the market, e.g. in the initial period of a simulation $t = 0$.

The total investment in the current technology of a firm, $E_{j,t}$, is the sum of investments $e_{j,t}$ over time. We assume that the incumbent has to give up his former technology and forfeit his prior investments, if he decides to switch to the disruptive technology:

$$E_{j,t} = \begin{cases} E_{j,t-1} + e_{j,t} & \text{if} \quad c_{j,t} = c_{j,t-1} \\ e_{j,t} & \text{else} \end{cases}, \tag{2}$$

where we assume that in the initial period of a simulation $E_{j,0} = 0$.

A firm's product position, a vector with components $x_{j1,t}, x_{j2,t}$, is defined as the firm's effective investment multiplied by the technology chosen:

$$\mathbf{x}_{j,t} = \ln(1 + E_{j,t})\alpha_{c_{j,t}}. \tag{3}$$

This means that, using a logarithmic transformation of the total investment, we suggest a simplified S-curve model where successive investments in a technology show decreasing returns to scale.

A firm's total cost consists of two components: fixed cost and investment cost. Regarding the fixed cost, we assume a factor $\gamma > 0$ on total investments. Through the investment cost, we model organizational inertia by introducing a factor $\kappa \geq 1$ that scales the investments of a firm without inertia:

$$C_{j,t} = \gamma E_{j,t} + \kappa^{e_{j,t}} e_{j,t}. \tag{4}$$

Thus, while a level of $\kappa = 1$ describes a situation where a firm is faced with linear increases in cost for linear improvements of its technological position in a single period, $\kappa > 1$ punishes fast technological progress by exponentially increasing investment cost. This means, it is cheaper for a firm to reach a specific level of investment within more periods, i.e., the organization is inert. However, as a consequence of the simplified S-curve model, a linear increase in a firm's position leads to an exponential increase in total cost, even if the firm is not inert. Therefore, cost acts as a bound on investments.

Market:

Following [1], we assume that the behavior of a consumer is guided by a Cobb-Douglas utility function with two arguments: product performance $y_{ij,t}$ and price $p_{j,t} > 0$ with the parameter $\beta > 0$ balancing the importance of product performance versus price:

$$u_{ij,t} = y_{ij,t}^{(1-\beta)}(1/p_{j,t})^{\beta} \tag{5}$$

Product performance depends on the feature levels $x_{jl,t}$, performance thresholds $d_{il,t} > 0$, and the relative preferences for the features $\eta \geq 0$, again in the form of a Cobb-Douglas function:

$$y_{ij,t} = \begin{cases} 1 + (x_{j1,t} - d_{i1,t})^{\eta}(x_{j2,t} - d_{i2,t})^{1-\eta} & \text{if} \quad x_{jl,t} > d_{il,t}, \\ & \qquad l \in \{1,2\} \\ 0 & \text{else} \end{cases}. \tag{6}$$

We assume that a consumer considers a product for choice only if its utility exceeds an overall utility threshold $u > 0$, i.e. $u_{ij,t} > u$, and chooses one unit of the product with maximum utility (denoted by $s_{i,t} \in \{1,2\}$). Ties are broken with equal probability and in order to avoid artificial results, we assume that consumers are indifferent between products with too small a difference in utilities. From the definition of the utility function it follows that the choice set is empty, if the available products do not satisfy the performance and implicit price thresholds.

Parameters η, β and u describe general market conditions and are thus assumed equal for all consumers. Consumer heterogeneity is introduced by a distribution of $(d_{i1,t}, d_{i2,t})$.

We study both time-constant and adaptive consumer thresholds. Using time-invariant preferences, consumers are not influenced in their preferences by technological progress, i.e. $d_{i,t} = d_{i,0}$. In the case of adaptive consumer behavior, which we indicate by the switch variable $\zeta \in \{0,1\}$, the minimal performance thresholds are adapted according to the direction and rate of improvement of the product purchased:

$$d_{il,t+1} = d_{il,t} \cdot \begin{cases} \frac{x_{c_{i,t}l,t}}{x_{c_{i,t}l,t-1}} & \text{if} \quad \zeta,\ x_{c_{i,t}l,t-1} > 0 \\ 1 & \text{else} \end{cases}. \tag{7}$$

This means that if the features of a product increase by, say 10%, the buyers of this product also increase their minimal performance requirements by the same percentage. In case the product was just launched, consumers do not change their requirements as there was no improvement. Note that this type of adaption process preserves the initial orthogonal distance of a preference position to the trajectory of a technology, which prevents the threshold distributions from becoming too singular over time.

Firm's Decision:

Besides technology choice, in each period of time a firm has to decide on a proper level of investment and price. We assume the firms to be well-informed—i.e., they know the consumers' utility functions and their competitors' past actions—to be rational—that is, they make optimal best response decisions—and myopic—they have a one-period forecast horizon.

The equations from the preceding paragraphs can be reformulated so as to express a consumer's reservation price for a product as a function of a firm's investment and price, given the consumer's current preference and the utility of the competitor's product. By reservation price we mean the maximum price a consumer is willing to pay for a product, which is all we need to know in order to define a demand function. Note that this price can be zero for some consumers and that we assume that the degree of price differentiation utilized by a firm is smaller than the consumer's threshold of indifference. This results in random choices among similar products and reasonable market outcomes. For ease of presentation, let $\hat{D}_{c_{j,t},t}$ denote the demand forecast of firm j using technology $c_{j,t}$ in period t, based on the information about the market up to period $t-1$. Then we can summarize the profit maximization problem of a firm as follows:

$$\begin{aligned} \hat{\pi}_{j,t} &= p_{j,t}\hat{D}_{c_{j,t},t} - C_{j,t} \rightarrow \max_{c_{j,t},\, e_{j,t},\, p_{j,t}} \qquad (8)\\ \text{s.t.} \quad & c_{1,t} = 1 \ \text{ if } \ t < \tau, \\ & c_{2,t} = 0 \ \text{ if } \ t < \tau, \\ & c_{2,t} = 2 \ \text{ if } \ t \geq \tau, \\ & e_{j,t} \leq F_{j,t}. \end{aligned}$$

By $F_{j,t}$ we denote a firm's current funds, that is cumulated profits plus initial funds. Although the constraint on investments implies that we do not consider the possibility of external funding, we can always relax this constraint by a proper choice of $F_{j,0}$. Further, we assume that a firm leaves the market, if it does not expect a positive profit or if its funds have become negative.

We suggest the following route to solving the optimization problem:

1. Choose a technology $c_{j,t}$ and generate a random trial value for investment $e_{j,t}$ drawn from $(0, F_{j,t})$.
2. Compute the demand function and choose the price that maximizes sales, $p^*_{j,t}$, given $c_{j,t}$ and $e_{j,t}$.
3. Among the trial values generated choose the profit-maximizing investment $e^*_{j,t}$ given $c_{j,t}$.
4. Choose the profit maximizing technology $c^*_{j,t}$.

Figure 1 shows an example from our initial simulation experiments where we used a restricted search range and a reduced number of search steps. Obviously, the latter search parameter is crucial in finding near optimal solutions on cliffy topologies. However, note that the shape of the objective function depends on the stage and structure of a market.

3 Simulation Setup and Experimental Design

Based on the definitions given in the previous section, the emergence of different competitive scenarios is studied using the following scheme of a simulation:

The first step of a simulation is to initialize the population of consumers and setup the firms. Next, the incumbent enters the market with technology α_1. For the first three periods, the incumbent can act as a monopolist, and in the fourth period the entrant joins the market with the new technology $\alpha_2 \neq \alpha_1$, which from this time on is available to the incumbent ($\tau = 4$). The firms calculate their profit-maximizing strategies (including the option to leave the market) according to Equation 8, and consumers then make their utility-maximizing choices (including the option not to buy) according to Equations 5 and 6. In the case of adaptive preferences, the buyers further adapt their thresholds according to Equation 7. Finally, the market outcome is evaluated in terms of market share and profit.

Table 2 summarizes the setup of the invariant part of a simulation: the market consists of 100 consumers where a consumer's thresholds of acceptable product performance are drawn from a uniform distribution

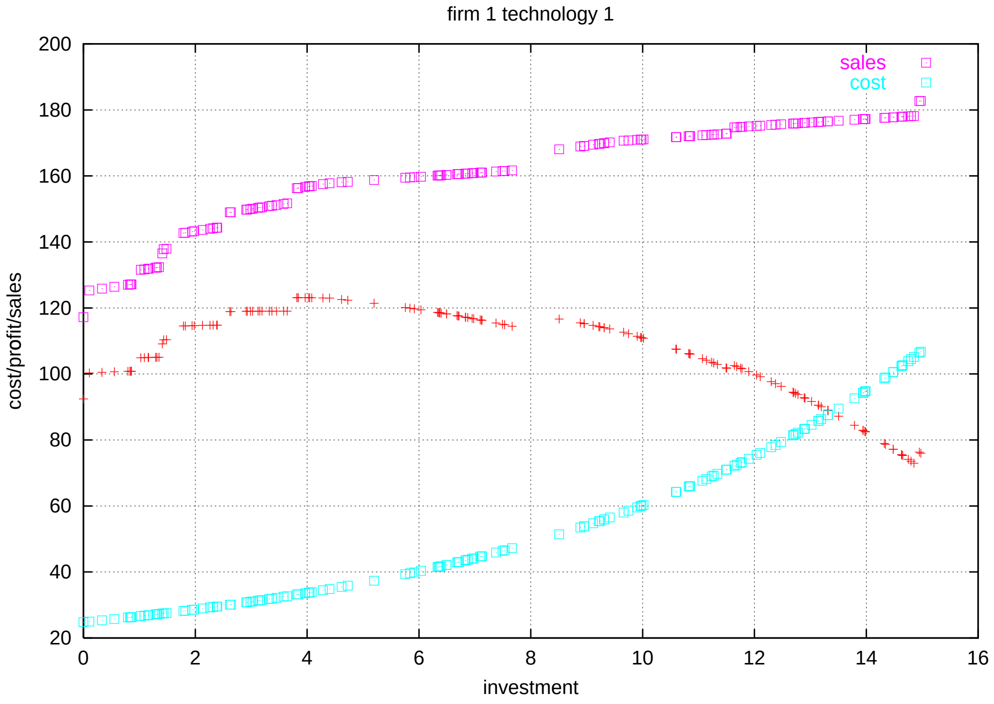

Figure 1: An Illustration of Random Search

Parameter	Value
τ	4
I	100
η	0.5
$F_{j,0}$	1000
γ	0.2
δ_1	$\pi/10$
δ_2	$\pi/4$
λ_1	1.0

Table 2: Model Setup

over the rectangle $(0, 3) \times (0, 3)$. Note that we hold the distribution constant across different simulations. For the overall utility threshold of the consumers, we assume a level that scales the reservation prices at zero surplus performance properly, i.e. such that $u^{-\beta} = 3$. For parameter η we choose a level of 0.5, meaning that for a consumer overcompensation of the minimum performance requirement of one feature is equally valuable as overcompensation of the other one. Thus, we do not model segments of relative preference as in [1], but a potentially competitive market that is segmentable by the firms' choices of technology, investments, and price.

With regard to the firms, we assume initial funds of 1000 monetary units and a fixed cost factor $\gamma = 0.2$, which ensures unconstraint investments and proper scaling with reservation prices (so that initially the incumbent can make a profit). We further assume a considerable bias of the incumbent technology against feature two ($\delta = \pi/10$) and a balanced entrant technology ($\delta = \pi/4$). That is, given the same level of total investment and equal efficiency, the entrant technology outperforms the incumbent's with respect to the second feature but is inferior in the first. Thus, the new technology fulfills Christensen's criterion of potentially disruptive technologies [4].

Figure 2 illustrates the key features of the market so far defined. The consumers' performance thresh-

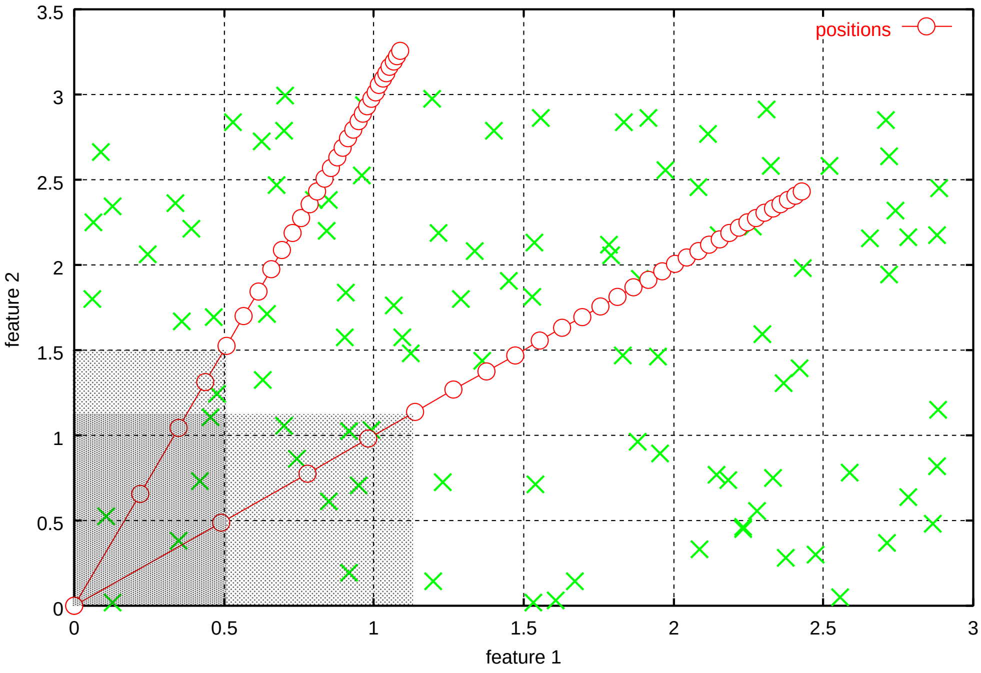

Figure 2: An Illustration of the Market Space

olds are drawn as crosses. The lines mark the technological trajectories for the incumbent (close to the vertical axis) and the entrant technology (45°), respectively. Points on these lines depict product positions corresponding to linearly increasing levels of total investment $(0, 1, 2, \dots)$ given equal technological efficiency. Thus, the market volume grows quadratically in the inner of the rectangle as the firms develop their products over time. The shaded areas illustrate that the utilization of the entrant technology implies a better market coverage, i.e., for equal levels of effective investments the number of potential buyers of the product based on this technology is always greater than for the other one (allowing for variations in the distribution of thresholds). Further, the ratio of exclusive to competitive market coverage is clearly in favor of the entrant technology.

We study the influence of specific model parameters on the competition between an incumbent and an entrant firm. Four competitive regimes can be distinguished according to technology choice and market shares:

- *Entrant Failure*
  The incumbent sticks to the initial technology but the entrant fails to capture a reasonable share of the market ($\leq 30\%$), or even does not enter the market.
- *Diverse Competition*
  The incumbent sticks to the initial technology, and the entrant can equal the incumbent in terms of market share ($\approx 50\%$).
- *Disruption*
  The incumbent sticks to the initial technology but the entrant is able to outperform the incumbent, i.e., the entrant gains a considerable share of the market ($\geq 70\%$), or even may force the incumbent out of the market.
- *Duopolistic Competition*
  The incumbent switches to the entrant technology and thus competes with the entrant on a similar product. Therefore, we expect the market shares to be rather identical ($\approx 50\%$).

Table 3 shows a full factorial design of the model parameters we consider relevant for market outcome. As we conjectured that relative technological efficiency and organizational inertia are key determinants of

Factor	Levels
λ_2	0.4, 0.6, ..., 1.8
κ	1.0, 1.1, ..., 1.3
β	0.5, 0.7
ζ	0,1

Table 3: Design Factors

the market outcome, we decided to search these parameters with a reasonably high resolution while economizing on the levels of price sensitivity. Thus, with $\lambda_1 = 1$ the range of λ_2 includes entrant technologies that are inferior, equal, and superior in terms of the incumbent's technological efficiency. Especially, we expect a considerable influence on the decision to switch and, thus, on the market outcome. With respect to organizational inertia κ, we analyze levels between 1.0 (no inertia) and 1.3 (high inertia). Note that in the present setting differentials in inertia are meaningless for the incumbent's technology choice at $t = \tau$, because information on the entrant product is not available by that time. By variation of β, we study the effect of high (0.5) and low (0.7) price elasticity, modeling the market's receptiveness to innovation. Further, we compare markets where consumers adapt their performance thresholds ($\zeta = 1$) to markets with static consumers ($\zeta = 0$). We expect adaptation to act in favor of the incumbent because initially, as a monopolist, he is able to thin out the low end of the market and thus could block out the entrant.

4 Results

The model was implemented in the mathematical language Octave[1], and the results were analyzed using the statistics software R[2]. The source code of the implementation is available upon request from the authors. A total simulation time of 20 periods proved sufficient to get a clear picture of the market outcome. Further, since our model is rather deterministic (random product choices should be rare except in duopolistic competition where they act as stabilizers on market share), the simulation was run repeatedly mainly in order to determine a proper calibration of the random search: using 1000 steps and a restriction on the upper search range provided stable results.

Figure 3 shows the outcome of a scenario with parameter combination $\lambda_2 = 1.1$, $\kappa = 1.1$, $\beta = 0.5$, and $\zeta = 1$: the incumbent's results are shown as solid lines, the entrant's are presented using dashed lines. Utilization of the initial (incumbent) technology is indicated by circles whereas lines marked with crosses indicate the use of the new (entrant) technology. The upper left graph shows profit over time, i.e., the success of a firm's actions. It can be seen that the entrant outperforms the incumbent from the fifth period on, since the incumbent does not switch to the new technology. In the upper right and lower right diagrams, we see that this outperformance results from both a higher unit price and a higher number of units sold. These higher unit prices can be asked because of higher product performance resulting, in turn, from higher investments (see the lower left diagram). The gap in investments also results in differences in market coverage, and therefore the entrant has a larger number of (exclusive) buyers (see Figure 2).

Figures 4 and 5 show aggregate results for all parameter combinations distinguishing between scenarios with static and adaptive performance thresholds ζ: we plot the entrant's average market share (vertical axis) for different levels of efficiency of the entrant's technology (horizontal axis). The average market share (in terms of profit) is defined as the mean of the shares from periods 11 to 20, i.e. when the market has already stabilized. Points marked with an '`x`' ('`o`') indicate a (no) switch of the incumbent to the entrant technology and points marked with a '+' failure of the entrant to enter the market. The subplots represent the results for different combinations of the remaining design factors: from left to right, the level of organizational inertia κ increases, from top to bottom the level of price elasticity β decreases.

First, we notice that the entrant is never able to outperform the incumbent if no organizational inertia exists ($\kappa = 1.0$), i.e., there exists no level of λ_2 where disruption occurs. The reason for this is the

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[1] `www.octave.org`

[2] `www.r-project.org`

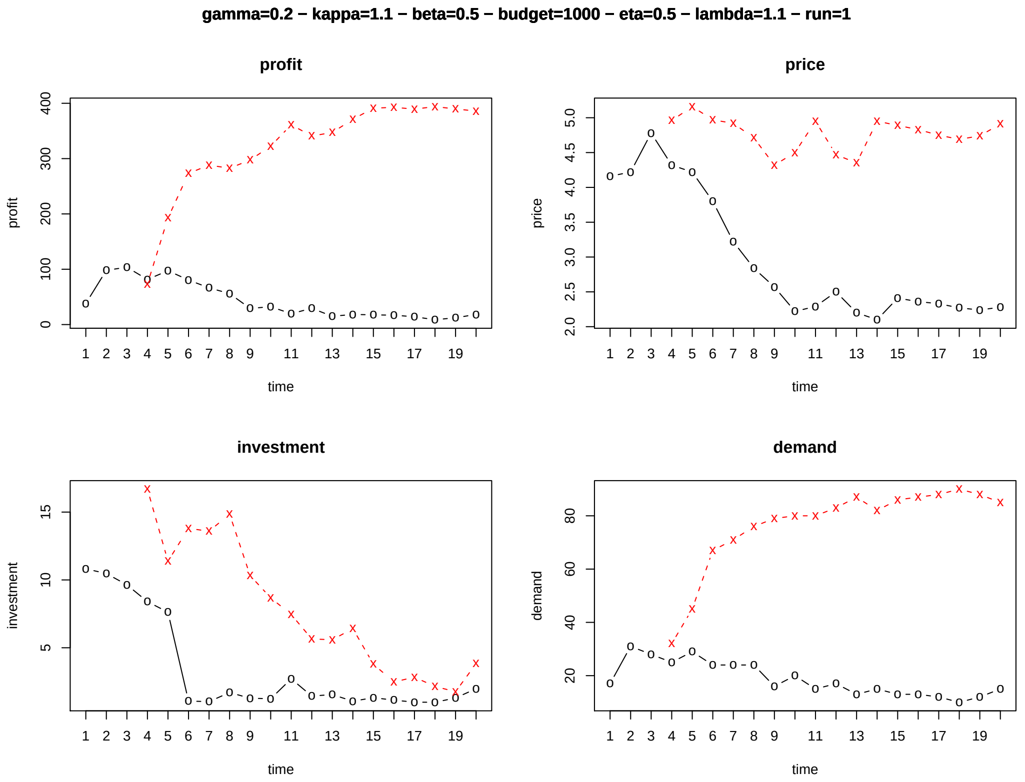

Figure 3: An Illustration of a Scenario

following: if the new technology is efficient enough, the incumbent switches (without exception in $t = 4$) and duopolistic competition emerges, which is characterized by rather balanced market shares. In case the market is targeted by different technologies, entrant failure or diverse competition is the outcome: the more inferior the entrant's technology is, the smaller is his market share. This is due to the fact that low investments result in a higher market coverage of the incumbent (see Figure 2).

All scenarios with $\kappa > 1$ show a different pattern as compared to the scenarios with $\kappa = 1$: now, we observe a range of efficiency in between diverse and duopolistic competition, where the incumbent does not consider it profitable to switch technology and subsequently looses a significant share of the market to the entrant, i.e., where disruption occurs. Obviously, the disruptive range does not considerably depend on whether consumers adapt their performance thresholds or not. In the case of adaptation, closer inspection reveals that—although the incumbent is able to maintain exclusive coverage of a small part of the market—he cannot catch up with the entrant, because the incumbent technology does not follow the main direction of the market and, therefore, the entrant's market is almost exclusive. Conversely, in the case of static consumer thresholds and disruption, the whole incumbent market is competitive whereas the entrant's one is by far more exclusive. Further, in the long run the entrant captures part of the incumbent market, since both firms lack the incentive to offer a distinguishable product to these consumers (see Figure 2).

Table 4 gives a summary of the ranges in the market outcome (distinguished by share and technology choice) for λ, switching times, and the number of no-entry failures (in parentheses). It further shows important aspects of our model: first, the breakpoints for switching do not increase with higher levels of inertia. Therefore, we are inclined to conclude that in our model disruption is mainly a result of myopic decision making. To understand this, notice that in the absence of organizational inertia investments are concentrated on the time of entry, which is rather similar to making a single, long-term decision, whereas with increasing inertia investments become more and more distributed over time. Now, as the firms have only a one-period horizon, they loose more and more their sense of long-term optimality. To be precise, the long-term levels of total investment are the lower the higher the level of organizational inertia, and that

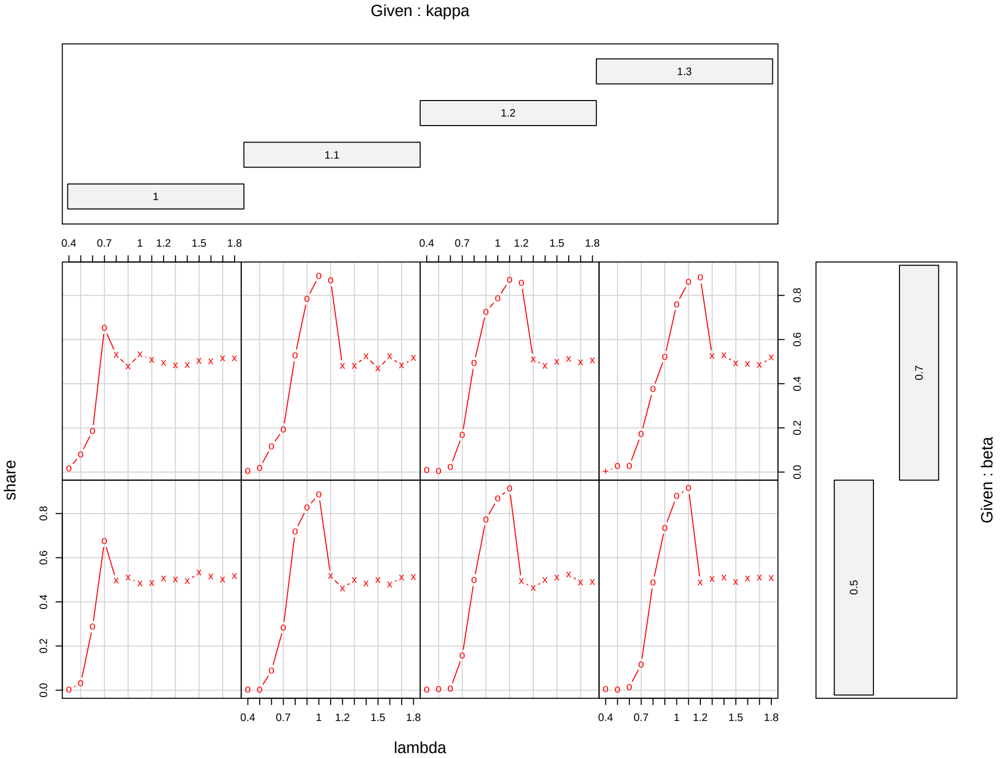

Figure 4: Results for Static Scenarios

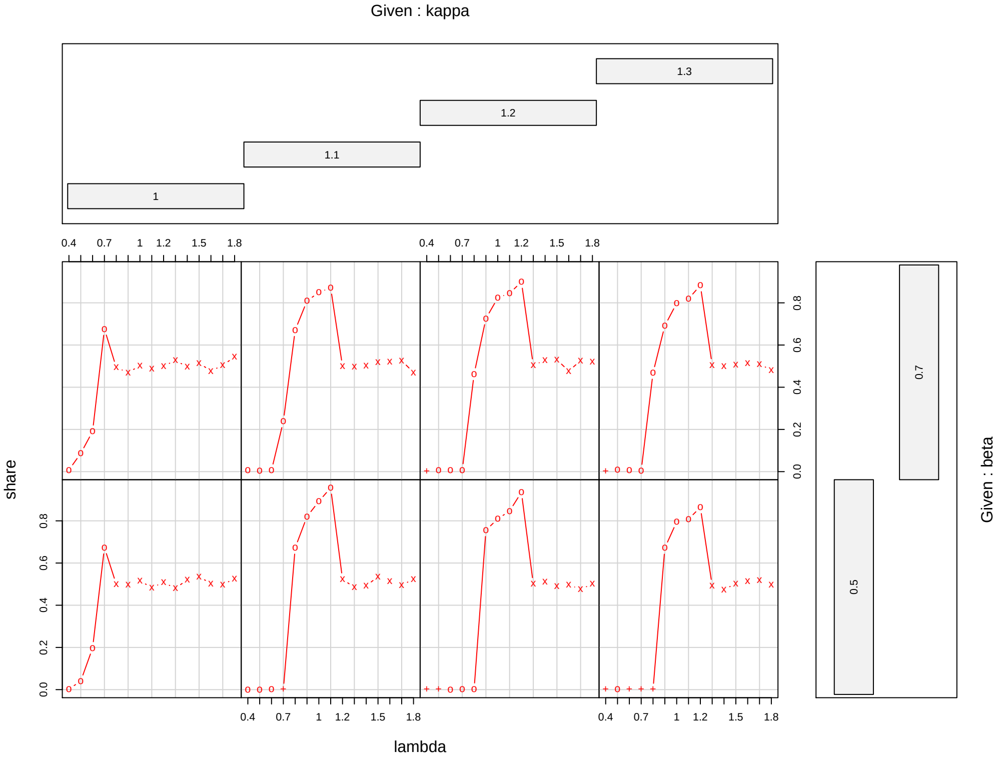

Figure 5: Results for Adaptive Scenarios

ζ	β	κ	λ				t
			failure ($\leq 30\%$)	diverse ($\approx 50\%$)	disruption ($\geq 70\%$)	duopolistic ($\approx 50\%$)	switch
0	0.5	1.0	0.4–0.6 (0)	0.7–0.7	-	0.8–1.8	-
		1.1	0.4–0.7 (0)	-	0.8–1.0	1.1–1.8	4
		1.2	0.4–0.7 (0)	0.8–0.8	0.9–1.1	1.2–1.8	4
		1.3	0.4–0.7 (0)	0.8–0.8	0.9–1.1	1.2–1.8	4
0	0.7	1.0	0.4–0.6 (0)	0.7–0.7	-	0.8–1.8	-
		1.1	0.4–0.7 (0)	0.8–0.8	0.9–1.1	1.2–1.8	4
		1.2	0.4–0.7 (0)	0.8–0.8	0.9–1.2	1.3–1.8	4
		1.3	0.4–0.7 (1)	0.8–0.8	0.9–1.2	1.3–1.8	4
1	0.5	1.0	0.4–0.6 (0)	0.7–0.7	-	0.8–1.8	-
		1.1	0.4–0.7 (1)	0.8–0.8	0.9–1.0	1.1–1.8	4
		1.2	0.4–0.8 (2)	-	0.9–1.1	1.2–1.8	4
		1.3	0.4–0.8 (3)	0.9–0.9	1.0–1.1	1.2–1.8	4
1	0.7	1.0	0.4–0.6 (0)	0.7–0.7	-	0.8–1.8	-
		1.1	0.4–0.7 (0)	0.8–0.8	0.9–1.1	1.2–1.8	4
		1.2	0.4–0.7 (1)	0.8–0.8	0.9–1.2	1.3–1.8	4
		1.3	0.4–0.7 (1)	0.8–0.8	0.9–1.2	1.3–1.8	4

Table 4: Summary of Results

is—-besides disruption—clearly suboptimal.

Another important aspect of the present model is that the occurrence of disruption does not depend on possible differences in organizational inertia because we observed that switching takes place when there is no competitive information available, i.e. on the time of entry. Thus, even if the entrant is assumed to be less inert than the incumbent our results hold, only the range of efficiencies with disruptive market outcomes increases. Let us exemplify this for the static and adaptive scenarios by assuming $\kappa_1 = \kappa$ for the incumbent and $\kappa_2 = 1$ for the entrant, see Figures 6 and 7. Notice that in the case of duopolistic competition, the market shares of the entrant are slightly higher if price sensitivity is low, since the entrant can demand higher premium prices. Further, among the adaptive scenarios, there are cases of no entry as well as cases where the incumbent leaves the market (in $t = 18$), and thus the entrant's market share goes up. Clearly, low price sensitivity and a high differential in inertia is not in favor of the incumbent.

5 Conclusions

In this article, we have analyzed the influence of organizational inertia and technological efficiency on the emergence of competition between an established firm and an entrant. We have assumed that the firms maximize their profit expectation for the next period if there exists full information on the needs of the entire consumer market and the competitor's current product position and price, and that the incumbent has the choice to switch to the new entrant technology. Technologies are modeled as linear trajectories of possible product positions in a two-dimensional feature space. A simplified S-curve model describes the relationship between a firm's investments and its technological progress, which comes with increasing fixed cost and investment cost. The firms are faced with a highly competitive market of compensatory, utility-maximizing consumers with different minimum performance requirements. We have studied the influence of differentials in technological efficiency on the entrants' success under different market conditions and levels of organizational inertia.

Using an agent-based computer simulation we have shown that the entrant is never able to outperform the incumbent, if organizational inertia does not exist. This is an interesting finding as we expect organizational inertia to be higher for larger companies and/or complex industries. Reducing an organization's complexity is, therefore, advisable to large companies that are faced with potential entrants. This is consis-

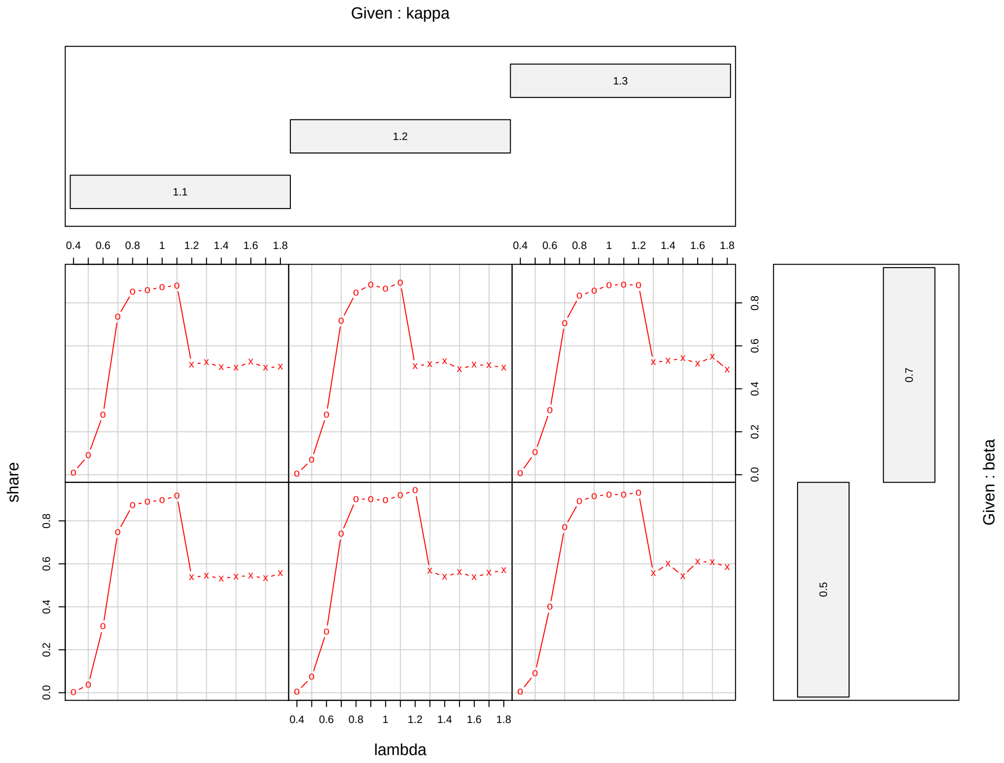

Figure 6: Results for Static Scenarios with Differential Inertia.

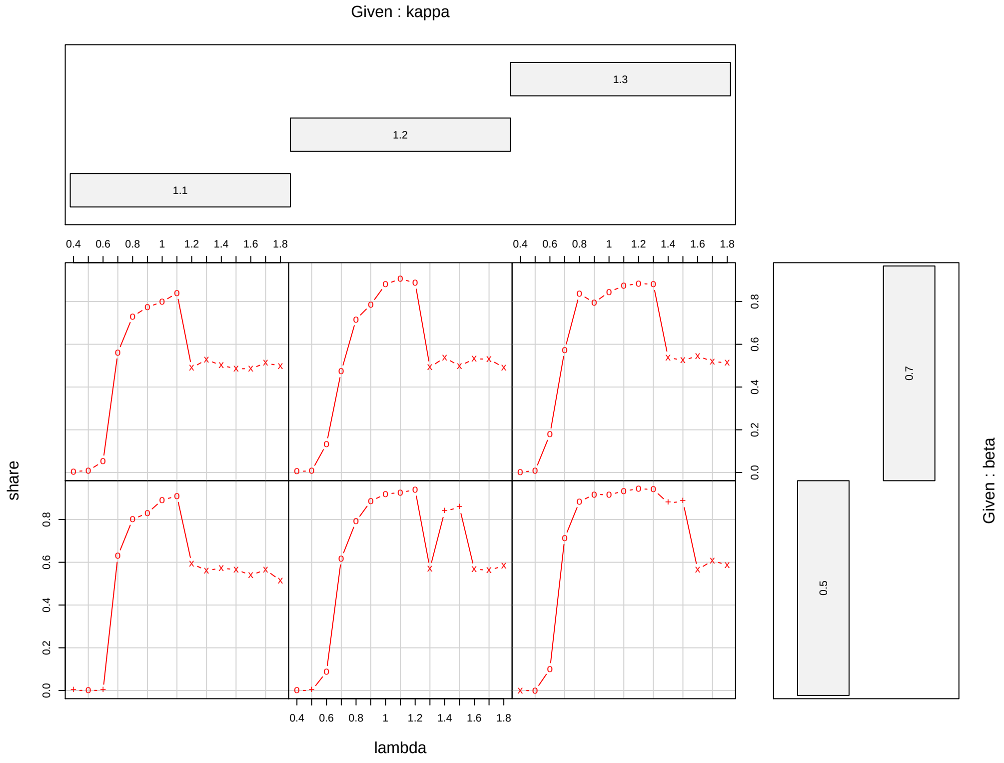

Figure 7: Results for Adaptive Scenarios with Differential Inertia.

tent with Christensen's suggestion that firms should not pursue the development of potentially disruptive technologies within their existing organization but ought better outsource this task to a new company.

Furthermore, we have found that outperformance of the incumbent firm depends on a specific range of the entrant's (relative) technological efficiency. If the new (disruptive) technology's efficiency is too low, the entrant is not able to reach a satisfactory product performance and thus is unable to capture a significant share of the market. On the other hand, if the efficiency is very high, it is more attractive to the incumbent to switch to the new technology than to continue with his initial one. The result is a duopolistic market where price competition between similar products prevails. Finally, we have found that differentials in organizational inertia expose the incumbent to an increased risk of disruption.

Both results regarding technological efficiency and organizational inertia are rather independent of the demand structure. In contrast to Adner, we therefore conclude that the phenomenon of disruption does not necessarily occur as a result of changes in consumer preferences, but that technological and organizational aspects seem to be more important. We expect that fully rational, long-term optimizing firms are better able to defend their market position even if organizational inertia exists. For this reason, it would be interesting to see further research in the direction of models where firms base their decisions on long-term forecasts of their competitors' technological moves. In particular, this should involve determining the proper planning horizon and suitable forecasting instruments.

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