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An Aspiration Adaptation Based Model of the Timing of Product Innovation

by

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Abstract

This paper applies the theory of aspiration adaptation to industrial economics. It is motivated by the question, frequently raised in the context of theoretical and empirical research on industrial innovation, of what triggers a firm's innovative activity. We develop a model of the management's decision-making relating a firm's competitive behavior, in particular the decision to start the development of a new product generation, to the current and past values of the firm's growth rate and profitability. This linkage offers an alternative perspective on the incentives for innovation. Furthermore, we explore the relationship between firm size and innovativeness resulting from our model.

JEL Classifications: D21, L11, L21, L25, O31

Keywords: Aspiration Adaptation, Bounded Rationality, Product Innovation

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1 Introduction

There is a school of thought in economics, going back to Herbert Simon (see e.g. Simon (1957)), which emphasizes the need for a positive theory of human decision-making in economic modelling. Drawing also on neighbouring disciplines such as psychology and sociology, it inspired the theory of *bounded rationality* (for a discussion of the main aspects of this theory, the reader is referred to Selten (2001)).

Although the profession has not agreed upon a unified approach,[1] one essential aspect of the theory of bounded rationality appears to be the assumption advocated for instance by Simon (1957), Cyert and March (1992), Sauermann and Selten (1962) and Selten (1998) that individual decision-making involves multiple incomparable goal variables. An abstract framework for modelling the process of individual decision-making with multiple incomparable goal variables has been formulated by Sauermann and Selten (1962)[2] and termed *aspiration adaptation theory*.

This paper applies the theory of aspiration adaptation to industrial economics. It is motivated by the question, frequently raised in the context of theoretical and empirical research on industrial innovation, of what triggers a firm's innovative activity.[3] We develop a model of the management's decision-making relating a firm's competitive behavior, in particular the decision to start the development of a new product generation, to the current and past values of the firm's growth rate and profitability.

The realized values of the firm's growth rate and profitability are obtained from a semi-phenomenological model of an evolving market with many heterogenous firms. The semi-phenomenological model is specified in accordance with stylized facts about the dynamics of product life cycles.

The structure of the paper is as follows. In Section 2, our model of a firm's decision-making based on the concept of aspiration adaptation is described. In Section 3, the model is closed by a semi-phenomenological description of the dynamics of individual sales volumes, growth rates and profitabilities over a product life cycle. In Section 4, we analyse the dynamics of our model. In particular, we analyse the conditions engendering product innovation and discuss the classical issue raised by Schumpeter, namely the relationship between innovativeness and firm size. Section 5 concludes the paper with a brief discussion of our results.

[1] See comments of H. Simon to A. Rubinstein in Rubinstein (1998).

[2] For a recent exposition in English see Selten (1998).

[3] For an overview, see Cohen and Levin (1989), Reinganum (1989); in particular, the empirical study by Geroski et al. (2002) finds that innovative activity is sporadic and not tied to stable characteristics of firms.

2 The firm's decision-making as a process of aspiration adaptation

2.1 Goal variables of the firm's management

In this subsection, we argue that a framework with multiple incomparable goal variables naturally appears in a behavioral description of the decision-making processes within a business organization. Although we concentrate on the case of a corporate firm, i.e. a business organization with separation of ownership from control, our argument applies to other organizational structures as well (see Section 5).

The decision-making entity of a corporate firm is the management, a hierarchical organization comprising several individuals on each level. The focus of this paper being on the decision as to when to invest in the development of a new product generation, we will be concerned with the decision-making of upper management, since the latter is responsible for this particular decision.

It is widely acknowledged in the organization literature that the individual manager's principal goal is her professional success within the organization (see e.g. Crozier and Friedberg (1993)). As each manager's professional success depends on how her work is evaluated, she will try to control those variables upon which the evaluation is based. If we focus on upper management, the evaluating institutions are the board, the shareholders and, less directly, the stock market.

Unlike the traditional approach in industrial economics, we do not assume that agents are endowed with a market model in which the relationship between the actions of the decision-makers involved and the market outcome is specified.[4] Instead, we assume that the evaluating institutions rely on business performance indicators in assessing to which extent the work of the management is conducive to the achievement of their goals (e.g. market value, long-term survival). Consequently, their evaluation of the manager's work must be based to a large extent upon these indicators of the firm's business performance. As a result, to promote their principal goal of professional success, the members of the upper management will try to control the realizations of the business performance indicators.

The crucial point is, however, that the manager does not know how the realizations of each of the indicators will be aggregated by the evaluating institutions to produce an overall evaluation of her work, as the aggregation reflects the relationship as perceived by the evaluating institutions between their goals and the performance indicators. Thus

[4] If we specified a market model, then the evaluating institutions would be able to directly infer the most appropriate actions with respect to their goals.

for each manager, the performance indicators of the firm become incomparable goal variables.

To avoid modelling how individual members of upper management, possibly concerned with different sets of indicators, reach agreement, we assume in this paper that *sales growth* and *profitability* are the only business indicators perceived as relevant by members of upper management for the assessment of their professional performance. With this assumption, growth rate of sales and profitability are the management's incomparable goal variables.

2.2 Search rules

2.2.1 Local procedural preferences

In the following, we introduce the basic notions of the aspiration adaptation theory (Sauermann and Selten (1962)). Let G^j and P^j denote the goal variables growth rate of sales and the profitability, respectively, of the management of firm j. By g_t^j and p_t^j we denote the associated realizations in time period t. In aspiration adaptation theory, an *aspiration level* is a vector of values for the goal variables. The set of all possible aspiration levels is a discrete set called aspiration grid. In our case, the aspiration grid referring to firm j is a subset of $\mathbb{R}^2$ and will be denoted by $\mathcal{L}^j$ with generic element (a_{G^j}, a_{P^j}). The components a_{G^j} and a_{P^j} are called partial aspiration levels. Throughout our paper we assume that $\mathcal{L}^j$ is identical for every firm.

In each period the management's principle decision is to set a target value, i.e. a particular aspiration level, for growth rate and profitability to be reached by the firm in the following period. An aspiration level set as target value for the period t by the management of firm j will be denoted by $(a^t_{G^j}, a^t_{P^j})$.

The incomparability of goal variables implies that no complete preorder on the set of aspiration levels can be assumed. Therefore, the traditional paradigm of optimization cannot be applied to the modelling of the management's decision problem.

Instead, the aspiration adaptation theory proposes that the choice of an aspiration level is a process of searching for a "satisfying" aspiration level guided by local procedural preferences, i.e. preferences ranking aspiration levels neighbouring a given one. Local procedural preferences comprise an *urgency order* and a *retreat variable*. For any given aspiration level (a_{G^j}, a_{P^j}), the urgency order $u_t^j(a_{G^j}, a_{P^j})$ ranks the importance, as perceived by the decision-maker, of an upward increase of the partial aspiration levels. The retreat variable $r_t^j(a_{G^j}, a_{P^j})$ characterizes that goal dimension with respect to which the decision-maker is ready to sacrifice ground, if unavoidable (in a sense that will be explained later), at the aspiration level (a_{G^j}, a_{P^j}).

Selten (1998) does not elaborate on the formation of the urgency order and the retreat variable. In the context of the present paper, we propose a particular rationale for the formation of a manager's local procedural preferences, involving a comparison of the manager's own firm's performance with a measure of the average performance in the market.[5] As a result, urgency order and retreat variable will be endogenous in our model.

As the average measure of performance with respect to growth rate at time t, the manager perceives the *market growth rate* $\overline{g}_t$:

$$\overline{g}_t = \frac{\text{aggregate sales volume at } t - \text{aggregate sales volume at } t-1}{\text{aggregate sales volume at } t-1}, \tag{1}$$

and with respect to profitability, the *average profitability of the market*, $\overline{p}_t$

$$\overline{p}_t = \frac{1}{|\mathcal{F}_t|} \sum_{i \in \mathcal{F}_t} p_t^i, \tag{2}$$

with $\mathcal{F}_t$ the set of firms active in the market at time t and $|\cdot|$ denoting the cardinality of a set.

For any aspiration level $(a_{G^j}, a_{P^j}) \in \mathcal{L}$ the manager of firm j forms her urgency order u_t^j and the retreat variable r_t^j based on the comparison of the relative deviations of her own firm's performance and the reference market values $\overline{g}_t$ and $\overline{p}_t$ in the following way:

$$u_t^j(a_{G^j}, a_{P^j}) = \begin{cases} (G^j, P^j) & \text{if} \qquad \frac{g_t^j - \overline{g}_t}{\frac{1}{t}\sum_{t' \leq t} \overline{g}_{t'}} \leq \frac{p_t^j - \overline{p}_t}{\frac{1}{t}\sum_{t' \leq t} \overline{p}_{t'}}, \\ (P^j, G^j) & \text{else} \end{cases} \tag{3}$$

with (G^j, P^j) denoting the situation that G^j is the most urgent, P^j the second most urgent goal variable. The retreat variable $r_t^j(a_{G^j}, a_{P^j})$ is assumed to be the least urgent variable with the exception of one specific case, which will be described in more detail in Section 2.4.

The above specification captures the idea that not knowing how the realizations of the indicators growth rate and profitability will be aggregated by the evaluating institutions to reach an overall assessment of her work, the manager will take the performance of other firms as point of reference and will avoid lagging behind in any of the goal variables.[6]

Further, we assume that at each firm j all members of upper management form their procedural preferences in the way described above, and in particular that they agree

[5] To make such a comparison more straightforward, we assume a market with all firms engaged only in this market.

[6] Of course, it is possible that the firm's performance lies above the reference values for both goal variables. In that case, as specified by equation (3), the manager will give priority to that goal variable where the firm performs less well.

upon the reference values specified in equations (1) and (2). Therefore, no aggregation problem arises, and we can speak of the manager's and the management's local procedural preferences interchangeably.

2.2.2 Minimal acceptable aspiration levels

Now we introduce an additional element into the aspiration adaptation framework, a notion we call *minimal acceptable aspiration level.* It is the minimal aspiration level tolerable by the firm's control authorities, board and shareholders. If these levels are no longer feasible for the firm, the control authorities might consider replacing the management (see e.g. Marris (1999), Pfeffer and Salancik (1978)).

What is tolerable is assumed to depend on the average performance of the market represented by the reference values from equations (1) and (2). We specify the minimal acceptable aspiration levels for growth rate and profitability, $\underline{a}_{G,t}$ and $\underline{a}_{P,t}$, as:

$$\underline{a}_{G,t} = \alpha_1 \cdot \overline{g}_t \tag{4}$$

$$\underline{a}_{P,t} = \alpha_2 \cdot \overline{p}_t, \tag{5}$$

with some fixed parameters $\alpha_1 \in [0,1]$ and $\alpha_2 \in [0,1]$. Note that, in accordance with the assumption of discrete aspiration levels, we round the numerical values of aspiration levels in calculations. To simplify notation, we do not explicitly indicate the rounding of aspiration levels in our exposition.

2.3 Construction of the expected feasible set

2.3.1 Actions

To reach some aspiration level the management of firm j employs a vector of *instrument variables* $X_t^j = (X_{1,t}^j, X_{2,t}^j, ..., X_{m,t}^j)$ with values in $\mathbb{R}^m$ denoting the firm's level of activity - measured for example by expenditures - in production, product differentiation, advertising, price, R&D efforts aimed at process innovation, or R&D efforts aimed at product innovation. A *plan*, $x_t^j \in \mathbb{R}^m$, is a vector of values for the instrument variables in some period t. An *action* modifies the plan undertaken in the last period (with no change of the plan also being a permissible action). In the aspiration adaptation framework the boundedly rational decision-maker is assumed to consider routinely only a finite set of actions. These actions might be for instance an increase in the level of expenditures for advertising, or a price decrease relative to the plan undertaken in the past period.

Taking account of the hierarchically organized structure of business organizations with the upper management delegating the choice of a concrete action to the specialized divisions of the business organization, we make the following abstraction from the abovementioned concrete set of actions:[7] We assume the upper management to consider a set of actions that consists of only four types of actions. The first type, denoted by A^g consists of those actions that are expected to increase the value of the growth rate with negligible effect on the profitability. The second type, $A^{g \wedge p}$, includes the actions that are expected to have a positive effect on both goal variables, whereas the third type includes the actions that are expected to increase the value of profitability with negligible effect on the growth rate.

Whereas the actions $A^g, A^{g \wedge p}$ and A^p are aimed at increasing sales or profitability in the current market, the management of a firm can also decide to undertake efforts aimed at the development of a new product generation and thus opening a new market. This fourth type of actions, $A^{R\&D}$, has a more drastic influence on the values of both goal variables (see Figure (1) and Figure (2)).

At one point of time a firm is assumed to undertake either one of the three actions $A^g, A^{g \wedge p}$ or A^p, or one combined action $A^g \cup A^{R\&D}$, $A^{g \wedge p} \cup A^{R\&D}$ or $A^p \cup A^{R\&D}$. It is further assumed that once having undertaken one of the combined actions, a return to one of the single actions is excluded.

2.3.2 Expectation formation and expected feasible set

The management[8] is assumed to form expectations about the aspiration levels it expects to be able to reach in the next period by the actions considered. The set of such aspiration levels is called *expected feasible set* and denoted by $\mathcal{E}^j_{t+1}(g^j_t, p^j_t)$.

In this paper we assume that the management forms its expectations as to whether a specific aspiration level (a_{G^j}, a_{P^j}) is feasible for period $t+1$ based on the firm's current realization (g^j_t, p^j_t) and on the expected influence of both the firm's own actions and exogenous market trends. More specifically, the management expects that all aspiration levels, $(a_{G^j}, a_{P^j}) \in \mathcal{L}$, satisfying the following two equations can be reached in period $t+1$:

$$
\begin{aligned}
a_{G^j} &\leq g^j_t + \delta^{g,j}_{A^i,t} + \delta^g_{A^{R\&D}} + \delta^{g,j}_{exogenous,t} && (6)\\
a_{P^j} &\leq p^j_t + \delta^{p,j}_{A^i,t} + \delta^p_{A^{R\&D}} + \delta^{p,j}_{exogenous,t}. && (7)
\end{aligned}
$$

In the first of the above equations $\delta^{g,j}_{exogenous,t}$ denotes the expected influence of exogenous trends on the goal variable growth rate, $\delta^{g,j}_{A^i,t}$ the expected influence of the action A^i,

[7] See Cyert and March (1992, p.165): "We assume that an organization factors its decision problems into subproblems and assigns the subproblems to subunits in the organization."

[8] As in the last section, we assume that the individual managers constituting upper management of some firm j share the same expectation formation routine and therefore we can again speak of the manager's or the management's expected feasible set interchangeably.

with $i \in \{g, g \wedge p, p\}$ and $\delta^g_{A^{R\&D}}$ the expected influence of the action $A^{R\&D}$ on this goal variable. The notation is analogous in the second equation for profitability. The set of aspiration levels from the set $\mathcal{L}$ satisfying these equations constitutes the expected feasible set $\mathcal{E}^j_{t+1}(g^j_t, p^j_t)$.

In forming expectations the management cannot precisely discriminate among the influences exerted either by its own actions or by exogenous conditions on the values of its goal variables, due to our assumption that no market model is available to the management.

To form expectations about how market trends affect growth rate and profitability, the management relies in our model solely on the firm's past performance and predicts changes of the realization of its goal variables in an extrapolative way. Extrapolative expectation formation has been confirmed by various experimental and empirical studies investigating the prediction of future values of a time series from information on its past realizations (See for instance Hey (1994) for an experimental study and de Leeuw and McKelvey (1984) for an empirical study on how business firms form price expectations).[9]

With extrapolative expectation formation the exogenous influence on the two goal variables, growth rate and profitability, can be specified as follows:

$$\delta^{g,j}_{exogenous,t} = b_1(g^j_t - g^j_{t-1}) + b_2(g^j_{t-1} - g^j_{t-2}) \tag{8}$$

$$\delta^{p,j}_{exogenous,t} = c_1(p^j_t - p^j_{t-1}) + c_2(p^j_{t-1} - p^j_{t-2}). \tag{9}$$

The coefficients are assumed to be positive with $b_1 + b_2 \leq 1$ and $b_1 > b_2$, and analogously for the coefficients c_i.[10] To compute the expected exogenous influence on the two goal variables, $\delta^{(\cdot),j}_{exogenous,t}$, we assume in formulae (8) and (9) that the management does not take into account which particular type of action the firm undertook in preceeding periods. Such an assumption is justified if the influence of the firm's actions on a goal variable is small. It will turn out that this condition is indeed fulfilled for the individual growth rates within the market dynamics specified in Section 3. In that case the sum of the coefficients can be set near to one. On the other hand, if the influence of the firm's actions is significant, formulae (8) and (9) become less reliable. However, if the exogenous trend is weak (that condition will prevail for individual profitability), the coefficients can be set close to zero and as a result the relative contribution of the exogenous part of the expectations becomes small.

[9] Note that the time-evolution of growth rate and profitability in our model does not exhibit a cyclical structure. If it did, other prediction rules would seem to be more appropriate (see e.g. Leopold-Wildburger and Becker (1996)).

[10] Note that positive coefficients imply that the management expects no reversal of an underlying trend in the time evolution of growth rate and profitability.

Let us now turn to the expected influence of an action A^i with $i \in \{g, g \wedge p, p\}$. It is reasonable to assume the following order of effects:

$$\delta^{g,j}_{A^g,t} > \delta^{g,j}_{A^{g\wedge p},t} > \delta^{g,j}_{A^p,t} = 0 \tag{10}$$

$$\delta^{p,j}_{A^p,t} > \delta^{p,j}_{A^{g\wedge p},t} > \delta^{p,j}_{A^g,t} = 0, \tag{11}$$

with $\delta^{g,j}_{A^i,t} = \beta_t(A^i) \cdot g^j_t$ and $\delta^{p,j}_{A^i,t} = \gamma_t(A^i) \cdot p^j_t$, with the proportionality factors $\beta_t(A^i)$ and $\gamma_t(A^i)$ adjusted by the management in an adaptive way. Figure (1) depicts the construction and the characteristic structure of the expected feasible set $\mathcal{E}^j_{t+1}(g^j_t, p^j_t)$.

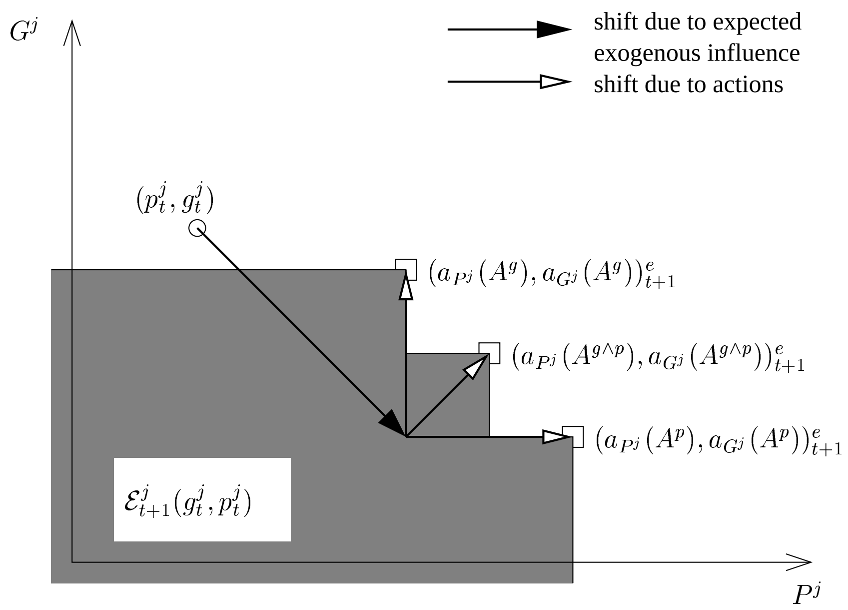

Figure 1: Construction of the expected feasible set $\mathcal{E}^j_{t+1}(g^j_t, p^j_t)$ with actions aiming at the current market only

To form expectations about the influence of action $A^{R\&D}$ on the firm's growth rate, i.e. to estimate $\delta^g_{R\&D}$, the management cannot rely on its own past experience. There are two aspects to that expectation formation. First, the management has to estimate the growth potential of a new market in the best case scenario (i.e. when the firm can launch the new product successfully and ahead of others). Typically, such estimates about the growth potential of a new market are provided by independent market research firms.

Second, the management has to estimate the probability of action $A^{R\&D}$ resulting in the successful launch of a new product. Kahneman and Lavallo (1993) convincingly argue that in estimating the odds of non-routine projects managers tend to be overconfident, neglecting discouraging statistics related to comparable projects undertaken by comparable organizations.[11]

[11] Note that, in fact, in Section 3 we model the consequences of action $A^{R\&D}$ as a stochastic process depending on the firm's size with the per-period probability of success being for example as low as 0.02305 for firms holding a market share of 10%.

Given the assumption that the management considers only one project at a time it does not seem reasonable to use expected values of the outcome of $A^{R\&D}$ in the construction of the expected feasible set, as the distinct feature of action $A^{R\&D}$ is that the consequences of this action are either the successful commercial introduction of a new product after the period in which the action was undertaken or a failure to do so. Thus, we assume that the overconfident manager uses the best case scenario value in her decision process.[12]

Whereas the action $A^{R\&D}$ is thus expected to increase the value of the firm's growth rate, the effect on short-run profitability will be strongly negative as R&D efforts have to be undertaken to develop the new product generation. Therefore, we have in equations (6) and (7) $\delta^g_{R\&D} >> \delta^{g,j}_{A^g}$ and $\delta^p_{R\&D} << -\delta^{p,j}_{A^p}$. Figure (2) depicts the construction of the expected feasible set taking into account the action $A^{R\&D}$.

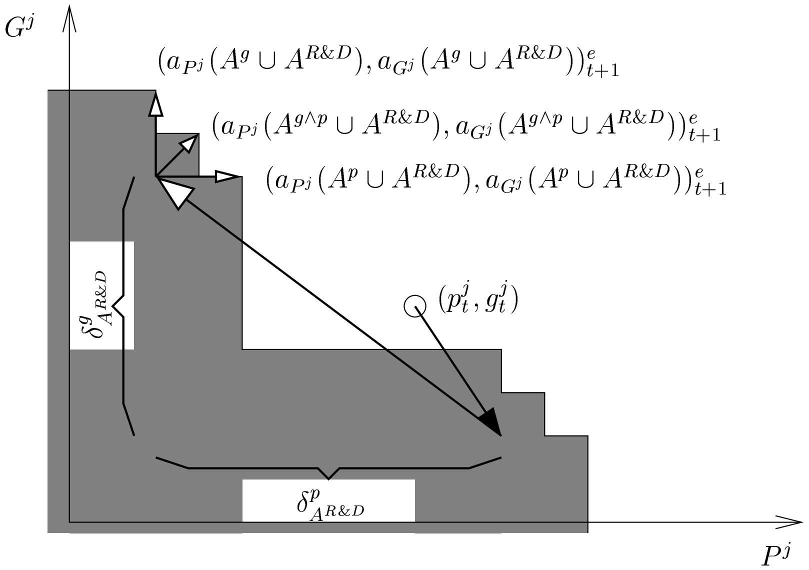

Figure 2: Construction of the expected feasible set $\mathcal{E}^j_{t+1}(g^j_t, p^j_t)$ in the general case, i.e. including actions aiming at the development of a new product generation

2.4 The process of aspiration adaptation

Aspiration adaptation is the process of local search for a *feasible acceptable* [13] aspiration level to be set as target value for the next period. This search starts with the aspiration level of the present period and is guided by the local procedural preferences, urgency order and retreat variable.

[12] It would not change anything in our model if we assumed that the manager discounts the best case scenario value by some factor. In fact, the crucial aspect is that $\delta^g_{R\&D}$ is much higher than what the management believes to be able to gain with respect to growth rate by undertaking the action A^g in the stages of the market evolution where market growth is low.

[13] A feasible acceptable aspiration level is throughout this paper understood as one lying within the expected feasible set and satisfying the minimal acceptable aspiration levels.

To illustrate the *aspiration adaptation process* as described in Selten (1998) let us assume that in period $t-1$ the firm j has chosen the aspiration level $(a^t_{G^j}, a^t_{P^j})$. The aspiration adaptation process depends on whether this aspiration level is feasible or not in period $t+1$, i.e. whether $(a^t_{G^j}, a^t_{P^j}) \in \mathcal{E}^j_{t+1}(g^j_t, p^j_t)$ or $(a^t_{G^j}, a^t_{P^j}) \notin \mathcal{E}^j_{t+1}(g^j_t, p^j_t)$. In the first case (Figure (3), left-hand side), the decision-maker must check whether an increase in the partial aspiration level of the most urgent goal variable to the next higher level, i.e. an upward adjustment, leads to a feasible acceptable aspiration level. If this is the case, at the new aspiration level thus reached, the decision-maker considers again whether an upward adjustment in the most urgent goal variable is feasible or not. If not, the decision-maker considers an upward adjustment of the second most urgent goal variable. If this upward adjustment is feasible, the decision-maker again reaches a new aspiration level. The search for a new aspiration level ends when no upward adjustment of any goal variable is feasible.

In the second case (Figure (3), right-hand side), the decision-maker is assumed to lower the partial aspiration level of the retreat variable by one level. By making this downward adjustment the decision-maker reaches a new aspiration level and again decides on upward or downward adjustments. The search ends if and when a feasible acceptable aspiration level is reached with no upward adjustments being possible.

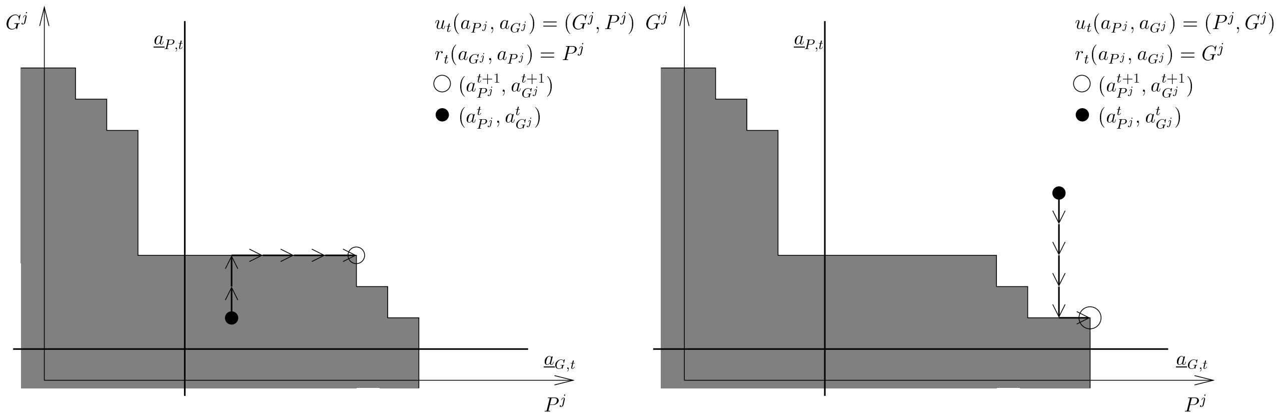

Figure 3: The process of aspiration adaptation; left-hand side: the current aspiration level lies within the expected feasible set; right-hand side: the current aspiration level lies outside the expected feasible set

In certain cases the aspiration adaptation process would not lead to an aspiration level within the expected feasible set even if there existed some feasible aspiration level satisfying the minimal acceptable aspiration levels. One such case is depicted in Figure (4) (left-hand side). This necessitates a slight modification of the aspiration adaptation process in that a downward adjustment in both variables and not only in the retreat variable is allowed.[14]

[14] In formal terms, we establish a retreat order, specifying as first variable the retreat variable, and

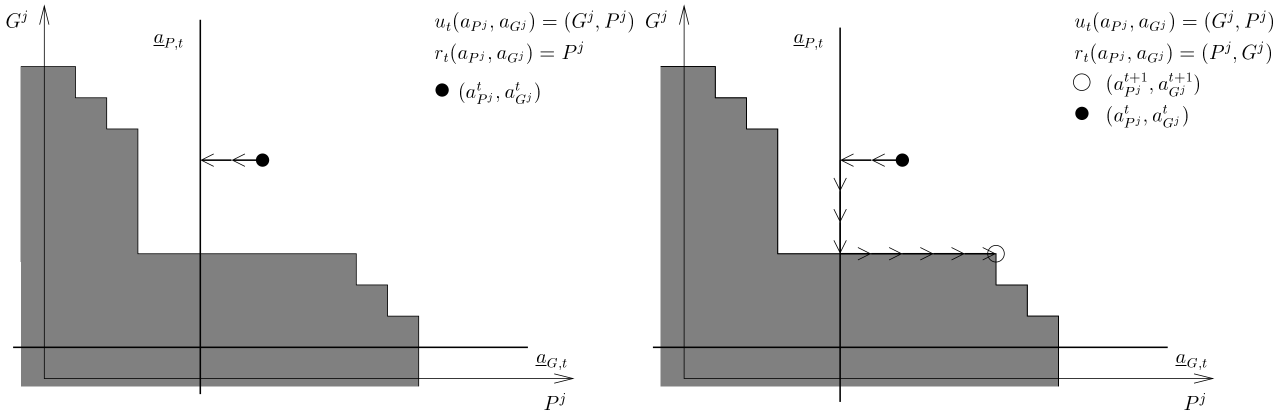

Figure 4: The process of aspiration adaptation when the minimal acceptable aspiration level is reached

It is important to emphasize that the search for aspiration levels described above is restricted to the set of aspiration levels satisfying the minimal acceptable aspiration levels. Thus, with the given structure of the expected feasible set and the interactively formed minimal acceptable aspiration levels, the latter imposing some minimal performance standard with respect to both goal variables, the management will search only within a subset of those aspiration levels it expects to be feasible.

Now we turn to the aspiration adaptation process in the case where no feasible acceptable aspiration level exists.[15] Such a situation corresponds to what Cyert and March (1992, p.188) refer to as "organizational failure" inducing "problemistic search". If, as in our case, the failure results from insufficient growth, product innovation, opening a new market with opportunities for considerable growth, is usually the only way out of the crisis. Cyert and March (1992, p. 188) remark:

> At one level, it appears that our general theory - especially the concept of problemistic search - is of considerable relevance to the prediction of innovations. We have argued that failure induces search and search ordinarily results in solutions. Consequently, we would predict that, everything else being equal, relatively unsuccessful firms would be more likely to innovate than relatively successful firms. Such a prediction is a legitimate derivation from the theory we have outlined where 'innovation' means a new solution to a problem that currently faces the organization.

However, striving for product innovation is costly, thus considerably diminishing profitability in the short term. It also involves a considerable degree of risk as it might lead the firm in an even more desperate situation should the project fail. As Cyert and March conclude, under "normal circumstances" the firm would refrain from undertaking

as second variable the other goal variable.

[15]If there do not exist any feasible aspiration levels which are acceptable at least with regard to the minimal acceptable aspiration level for profitability, we assume that the firm leaves the market.

product innovation efforts, searching instead for alternatives in the "neighborhood of existing policies":

> The neighborhood-of-existing-policy rule inhibits the movement of the organization to radically new alternatives (except under circumstances of considerable search pressure). Such an inhibition may be explained (...) in terms of some underlying organizational assumptions of continuity in performance functions (...).

However, Cyert and March argue that, "under circumstances of considerable search pressure", the organization will turn to a more "distant search" relative to the organizational procedures currently in use.

In our model, the performance assumptions precluding product innovation correspond to the requirement that the aspiration level chosen by the management as target value be above the minimal acceptable aspiration level with respect to profitability. Only if the evaluating institutions agree to a temporary abandonment of this requirement[16] can the management decide for product innovation and thus can set as aspiration level values from that part of the expected feasible set induced by those actions which include R&D efforts (see Figure (5)).[17] Note that a temporary lowering of the minimal acceptable level with respect to the growth rate does not offer the management a similar escape opportunity from the crisis.

Our specification of a firm's innovation investment decision implies that in case of a perceived crisis the management is willing to accept a higher degree of risk.[18] This is in agreement with Bowman (1982), Singh (1986) and Bolton (1993), whose findings, based on the work of Kahneman and Tversky (1979), indicate that firms with substandard performance tend to be strongly risk-seeking.

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[16] We believe that it is natural to assume that, facing the situation with no "painless" alternative available, the evaluating institutions of the firm will tolerate a period of profitability considerably below the market average during the development phase of a new product generation.

[17] To ensure that the decision to start the development of a new product generation does not result from a random and temporary downward deviation of expected growth rate, we stipulate that this decision can only be triggered if an acceptable feasible aspiration level does not exist for several consecutive periods. At this point we specify that a firm which has failed to find a feasible acceptable partial aspiration level with respect to growth rate will always choose action A^g in the following period. In that case the management still forms expectations about what aspiration levels it expects to be feasible but no longer adapts its aspiration level.

[18] Even if the evaluating institutions agree to the temporary abandoning of the minimal acceptable aspiration level for profitability, the management will be held responsible if the project fails.

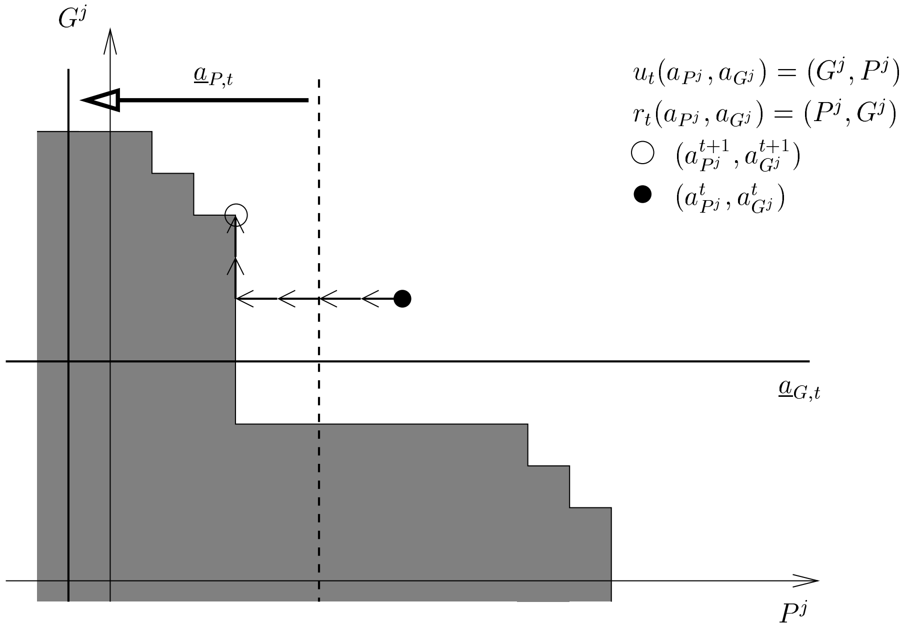

Figure 5: In the absence of feasible acceptable partial aspiration levels with respect to growth the minimal acceptable partial aspiration level for profitability will be lowered so that investment in the development of a new product generation enables the achievement of new growth opportunities for the future

3 A semi-phenomenological model of the time evolution of market structure within a product cycle

In this section, we present the second building-block of our paper, a semi-phenomenological model describing the time evolution of aggregate market sales as well as of the firms' individual market shares and profitabilities. In the model, the evolution of aggregate market sales is exogenous, whereas individual market shares are both dependent on the actions undertaken by the firms and subject to an exogenous trend favouring larger firms over smaller ones. The resulting phenomenon of concentration within a product life cycle is empirically well documented (see e.g. Geroski (1991)).

The semi-phenomenological model reproducing some stylized facts about the evolution of firm sizes, growth rates and profitabilities, combined with the decision model presented in Section 2 produces certain predictions about the relationship between the size and innovativeness of firms which will be presented in Section 4.

Characteristics of the time evolution of aggregate market sales over a product life cycle have been empirically researched in numerous papers. Several phenomenological models reproducing some stylized facts have been proposed. In our paper, we draw on a model proposed by Bass (1969) which provides a good approximation for the time evolution of aggregate market sales. Bass (1969) proposes that the evolution of aggregate

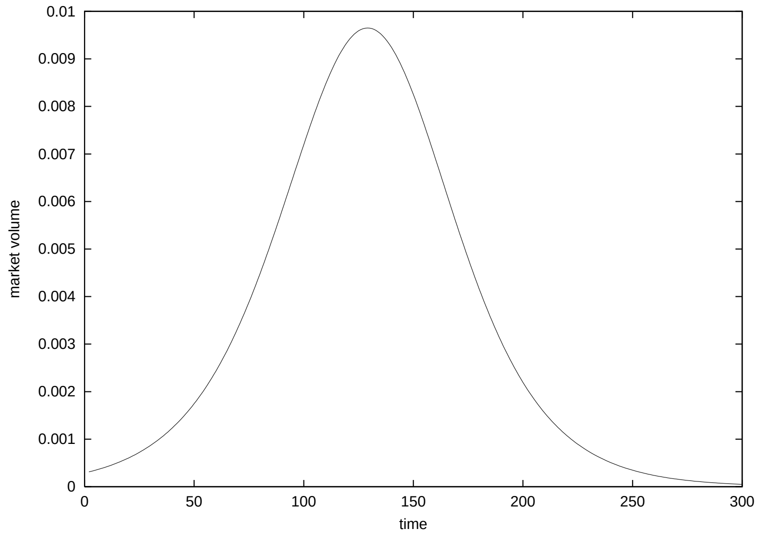

Figure 6: The evolution of aggregate market sales for a single product generation derived from Equation 12 (Bass (1969))

sales in period $t+1$ can be described by the following recursive equation:

$$f(t+1) = p(1-F(t)) + qF(t)(1-F(t)) \tag{12}$$

with $F(t) = \sum_{i=1}^{t} f(i)$ and p, q being empirical parameters which are industry and product specific. The values for the parameters of the Bass-Curve have often been estimated using different estimation procedures (for an overview see Mahajan, Muller and Bass (1990)). Figure (6) depicts the evolution of aggregate market sales resulting from equation (12) with the parameter values $p = 0.0003$ and $q = 0.038$ (for empirical fits see Sultan, Farley and Lehmann (1990)).

To obtain each individual firm's sales volume, y_t^j, we make use of the empirical observation that industry structures tend to concentrate during a product life cycle.[19] The empirical observation of increasing concentration can be formally captured by assuming that the market share $\mu_k(t+1)$ of firm k at time $t+1$ is determined by

$$\mu_k(t+1) = \frac{\mu_k(t)^{1+c(A_t^{i,k})\cdot f(t)}}{\sum_{j\in\mathcal{F}_t} \mu_j(t)^{1+c(A_t^{i,j})\cdot f(t)}} \tag{13}$$

with $\mathcal{F}_t$ being the set of firms active in the market at time t and $A_t^{i,j}$ being the action undertaken by firm j in period t with $i \in \{g, g{\wedge}p, p\}$. The influence of an action A^i, with

[19] Gort and Klepper (1982) analyzed the number of producers during the evolution of a market beginning with the first commercial introduction of the new product until the period of decay or contraction in absolute market size. Geroski (1991) summarizes their findings: "Following the commercial introduction of a product and an initial monopoly phase, net entry occurs, often at a phenomenal rate. Over time, net entry falls to zero and then becomes negative as exit occurs. Industry structures tend to concentrate at this stage, and the number of active firms declines until, again, net entry is zero."

$i \in \{g, g \wedge p, p\}$ on the individual market share of any firm j is characterized by $c(A_t^{i,j})$ which is a realization of a normally distributed random variable $C_t^j(A^i)$ where $(C_t^j(A^i))_{t,j}$ is identically independently distributed with $E(C_t^j(A^g)) < E(C_t^j(A^{g \wedge p})) < E(C_t^j(A^p))$ and $Var(C_t^j(A^i)) << 1$.

With the aggregate market sales in each period determined by equation (12) and an exogenous distribution of initial firms' sales volume, equation (13) yields the time evolution of sales for individual firms as well as of individual growth rates.

According to equation (13), a large firm increases its sales volume by an amount which is greater than the proportion of the additional market which would fall to the firm if the additional sales were divided according to the firm's market share in the preceeding period. This advantage to large firms will persist into the phase of market decline with larger firms retaining positive growth rates longer than smaller firms.[20]

We define profitability as the ratio of a firm's profit, π_t^j, to its sales, i.e. $p_t^j = \pi_t^j / y_t^j$. With the empirically justified assumption of 'mark-up pricing',[21] the profit of a firm j at time t is given by

$$\pi_t^j = m_t^j \; y_t^j \tag{14}$$

with m_t^j denoting the mark-up of firm j. Thus, the modelling of the time evolution of profitability is reduced to the modelling of the time-evolution of the mark-up, m_t^j.

We assume that the time evolution of an initially randomly assigned mark-up is determined by the actions the management takes and the firm's share of total profit:

$$m_{t+1}^j = m_t^j \cdot \left(1 + d(A^i) \cdot \frac{\pi_t^j}{\sum_{i \in \mathcal{F}} \pi_t^i}\right), \tag{15}$$

with $d(A^p) > d(A^{g \wedge p}) > d(A^g) = 0$.

The above equation captures the idea that the increase in the mark-up a firm can charge, which is related, for example, to the quality of a firm's products, its brand reputation, the amount of process innovation, etc., is proportional to the firm's share of total profit and thus to the competitive advantage the firm has in relation to other firms.

Now we turn to the specification of the impact of an action $A^{R\&D}$ on the realized values of the goal variables. To describe the fact that undertaking an action $A^{R\&D}$ will not immediately lead to product innovation, we employ a probabilistic characterization of per-period innovation success which is widely used in modelling product innovation (see e.g Aghion and Howitt (1998)). We assume that the per-period probability of

[20] In another paper (Hohnisch et al. (2003)) we explain the trend towards concentration over a product life cycle as a demand side effect resulting from interactive preference formation.

[21] For an empirical study on the price-setting behavior of firms in the US see for instance Blinder (1991), and for the UK Hall, Walsh and Yates (1997).

success of R&D efforts aimed at product innovation of firm j at period t depends on the size of the firm, as the firm's per-period level of investment in the development of a new product generation is proportional to its size.[22] Therefore we can specify the per-period probability of success as a function of a firm's size. Specifically, we assume that the probability of success is an S-shaped function of a firm's size, as depicted in Figure (7). The shape of the S-curve depends on the particular product technology, as different product technologies can be more or less capital intensive than others. For example, in the software industry a small firm might well be successful in developing a new product generation, but this is much less likely in the aircraft industry.

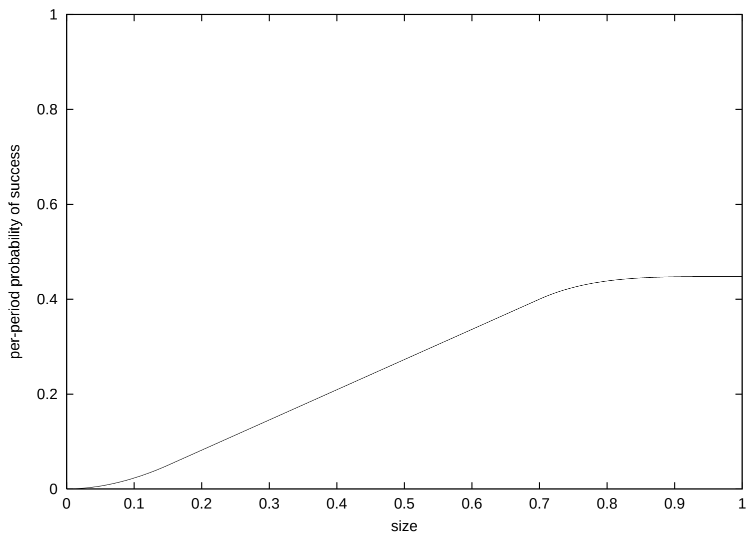

Figure 7: Per-period probability of success as a function of firm size (market share [%])

Thus, the management's expectation of higher growth rates might be realized only after some time has passed due to the difficulties involved in developing and launching a new product generation. Until and unless the action $A^{R\&D}$ has not led to the successful opening of a new market, the realized value for the goal variable growth rate will remain determined by the actions A^i, with $i \in \{g, g \wedge p, p\}$.

Whereas the effect of the action $A^{R\&D}$ on the growth rate is not immediate, profitability will be reduced by the increased expenditures on R&D aimed at product innovation. As explained above, the amount by which profitability is reduced is proportional to the firm's size.

[22] We assume a constant common for all firms.

4 Numerical analysis of market structure and innovativeness

In this section we present simulation results for the combined model consisting of the aspiration adaptation based decision model presented in Section 2 and the semi-phenomenological model of the evolution of market structure presented in Section 3.

We have run $200,000$ simulations of a product life cycle with the following specification of parameters: On average there are 15 firms active in each cycle at the beginning of the cycle. In each simulation run, their initial sizes are independently drawn from a lognormal distribution with mean value 0.0003 and standard deviation 0.000238. The initial realizations m_1^j for the mark-up of any firm j are independently drawn from a uniform distribution with support $[0.04, 0.06]$. The parameter values referring to the expectation formation are specified as follows: $b_1 = 0.5, b_2 = 0.3$, $c_1 = 0, c_2 = 0$ and $\beta_1(A^g) = 0.3$, $\beta_1(A^{g\wedge p}) = 0.15, \beta_1(A^p) = 0.0$ and $\gamma_1(A^p) = 0.1, \gamma_1(A^{g\wedge p}) = 0.05, \gamma_1(A^g) = 0.0$, $\delta^g_{R\&D} = 0.05$, $\delta^p_{R\&D} = 0.1$. The parameter values referring to the influence of the actions on the realizations of the two goal variables are specified as follows: $E(C_t^j(A^g)) = 0.1, E(C_t^j(A^{g\wedge p})) = 0.5, E(C_t^j(A^p)) = 0.9$ and $Var(C_t^j(A^i)) = 0.015$ and $d(A^p) = 0.09, d(A^{g\wedge p}) = 0.5, d(A^g) = 0.0$.

4.1 The time evolution of the individual growth rates and the distribution of firm sizes

The semi-phenomenological specification with endogenous choice of actions aims at reproducing the evolution of a market with the tendency towards concentration. In this subsection, some typical features of our model relating to the evolution of the size and growth rate of individual firms will be presented.

For each individual firm, the sequence of realized values for its growth rate and profitability depends on the actions undertaken both by this firm and by the other firms active in the market (cf. Equation (13)). In our model, these actions are decided upon by the management via the aspiration adaptation process. In addition to this causal element of the evolution, there is some degree of randomness involved resulting from the uncertain effects of actions A^g, $A^{g\wedge p}$, A^p reflected in the stochastic modelling of the influence of these actions. Technically speaking, we have a dynamical system subject to random noise in discrete time.

The inherent tendency towards concentration is reflected in two effects. Firstly, the variance of the distribution of individual market share increases over time as depicted in Figure (8). The solid line histogram corresponds to the initial distribution, which is by assumption lognormal. The dashed line corresponds to the distribution of individual market shares after 125 time periods, i.e. close to the peak of market volume. The data is obtained from approximately 200,000 simulation runs.

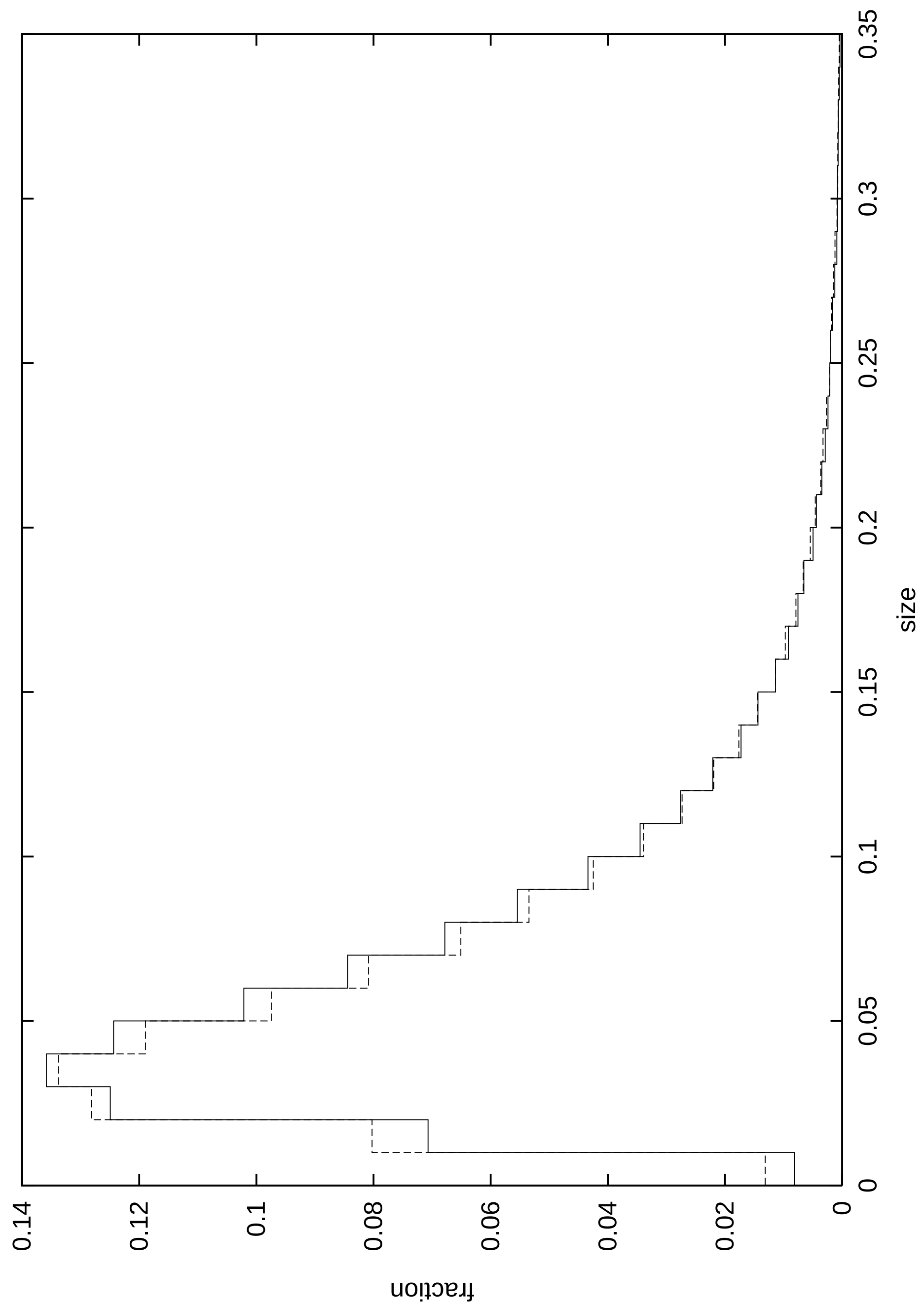

Figure 8: Distribution of firm size relative to total market (market share [%]) in the initial period (solid line) and in period 125 (dashed line); the data is obtained from approximately 200,000 simulation runs

Secondly, growth rates of smaller firms are, on average, below those of larger firms over almost the entire product life cycle. To visualize this effect, we have averaged for each time period the growth rate of firms with initial market share in the interval $[0, 0.05]$ and $[0.1, 0.15]$ with data from approximately 200,000 simulation runs. The result is depicted in Figure (9). The solid line represents the former category, the dashed line the latter.

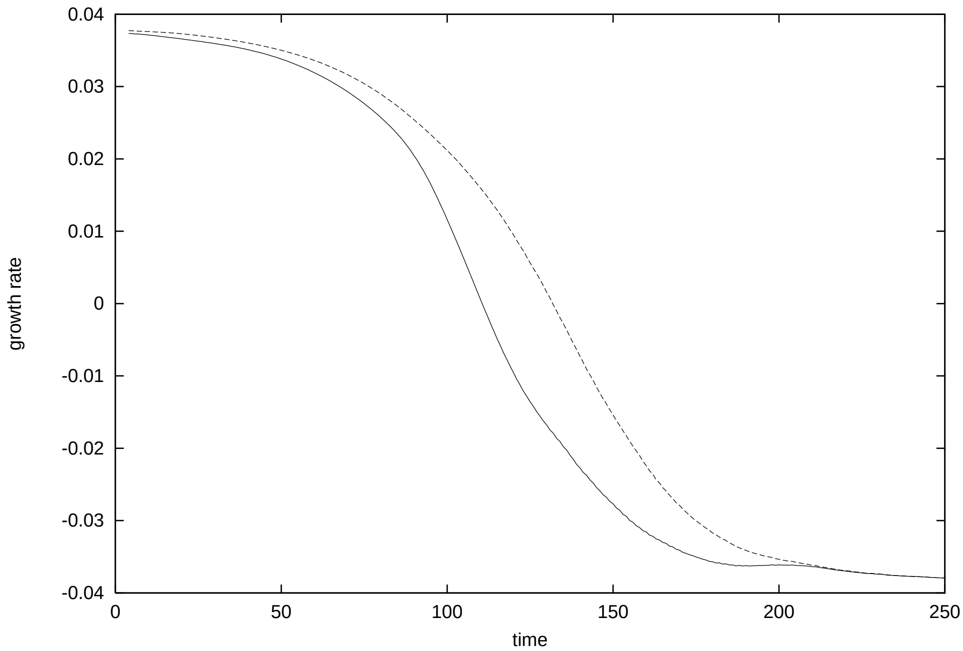

Figure 9: Average growth rates of firms differing in relative initial size; solid line: firms with initial market share [%] in the interval $[0, 0.05]$; dashed line: firms with initial market share in the interval $[0.1, 0.15]$ (200,000 simulation runs)

4.2 Timing of innovation and the relationship between size and innovativeness

Product innovation is endogenous in our model. The reader will recall that the management of a firm decides to start the development of a new product generation if it fails to find a feasible acceptable partial aspiration level with respect to growth for several consecutive periods while still having feasible acceptable partial aspiration levels with respect to profitability available. Thus, the process of aspiration adaptation within any given firm as well as the average performance of other firms jointly determine when a firm starts the development of a new product generation. The introduction of a new product occurs when one of the firms in the process of developing a new product is successful, with innovation success modelled by the random process specified in Section 3.

The distribution of the random variable corresponding to the period t_{start} in which development of a new product generation is initiated by one or several firms for the first time in a given product life cycle is depicted in Figure (10, top). Figure (10, bottom) depicts the distribution of the random variable corresponding to the period t_{inno} in which a new product is launched by one or several firms (By specification, the simulation run is terminated in that period).

The figures (11) and (12) depict two representative paths of the evolution of minimal acceptable partial aspiration level with respect to growth rate $\underline{a}_{G,t}$ (solid line), realized values for growth rate g_t^j ($\triangle$) and chosen partial aspiration level with respect to growth rate a_{Gj}^{t+1} ($\circ$) for two innovating firms with different initial size. In Figure (11) the firm chooses the action A^p until period 25, the action $A^{g\wedge p}$ in the following 5 periods and action A^g until period 95. Note that in period 96 and 97 the firm fails to find a feasible acceptable aspiration level.[23] Therefore, having abandoned the minimal acceptability criterion with respect to profitability, the firm chooses the action $A^{R\&D}$ from period 98 on, until successful innovation in period 126. In contrast, the larger firm (Figure (12)) decides upon $A^{R\&D}$ only in period 194, but is successful as early as period 204.

Our model allows analysis of the dependence of innovativeness[24] on size. There has been a long and controversial debate, initiated by Schumpeter (1934) and (1950), on whether large or small firms have the stronger incentives to innovate. For an overview, see Cohen and Levin (1989). It turns out that from the normative perspective, the answer depends strongly on the structure of the underlying game and a number of unobservable characteristics.

In our model the average size of the firm making a product innovation is affected by two factors, the first favouring large firms, the second small ones. The first effect reflects the higher per-period probability of success for larger firms (see Figure (7) and (11), (12)). Clearly, larger firms will invest more in the development of a new product generation, and thus will more probably be the innovator once the decision to start development of a new product generation has been made.

To explain the second effect, we first remind the reader that the minimal acceptable partial aspiration level with respect to profitability will, in the great majority of cases, prevent a firm from starting the development of a new product generation unless that level has been lowered due to successive failure to find feasible acceptable aspiration levels with respect to growth rate. Only if a firm happens to have extraordinary high

[23]Note that, in the case depicted, the firm fails to find a feasible acceptable partial aspiration level with respect to growth rate while still having feasible acceptable partial aspiration levels with respect to profitability. If the latter were not the case, the firm would leave the market.

[24]We use the term innovativeness for the probability of a firm being an innovator conditional on its size.

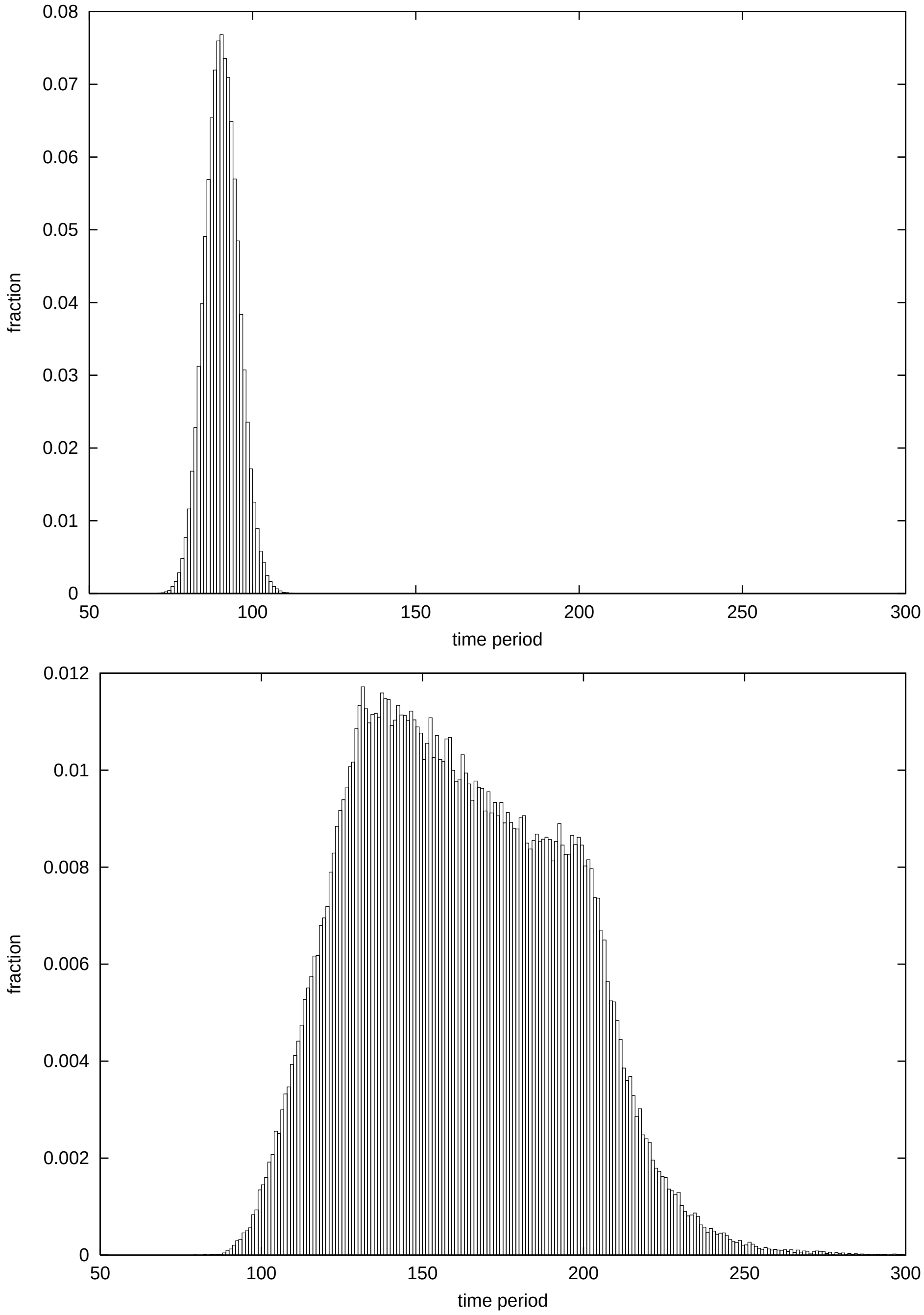

Figure 10: (top) distribution of the period t_{start} in which the development of a new product is initiated by one or several firms for the first time in a given product life cycle; (bottom) distribution of the period t_{inno} in which the new product is introduced by one or several firms (200,000 simulation runs)

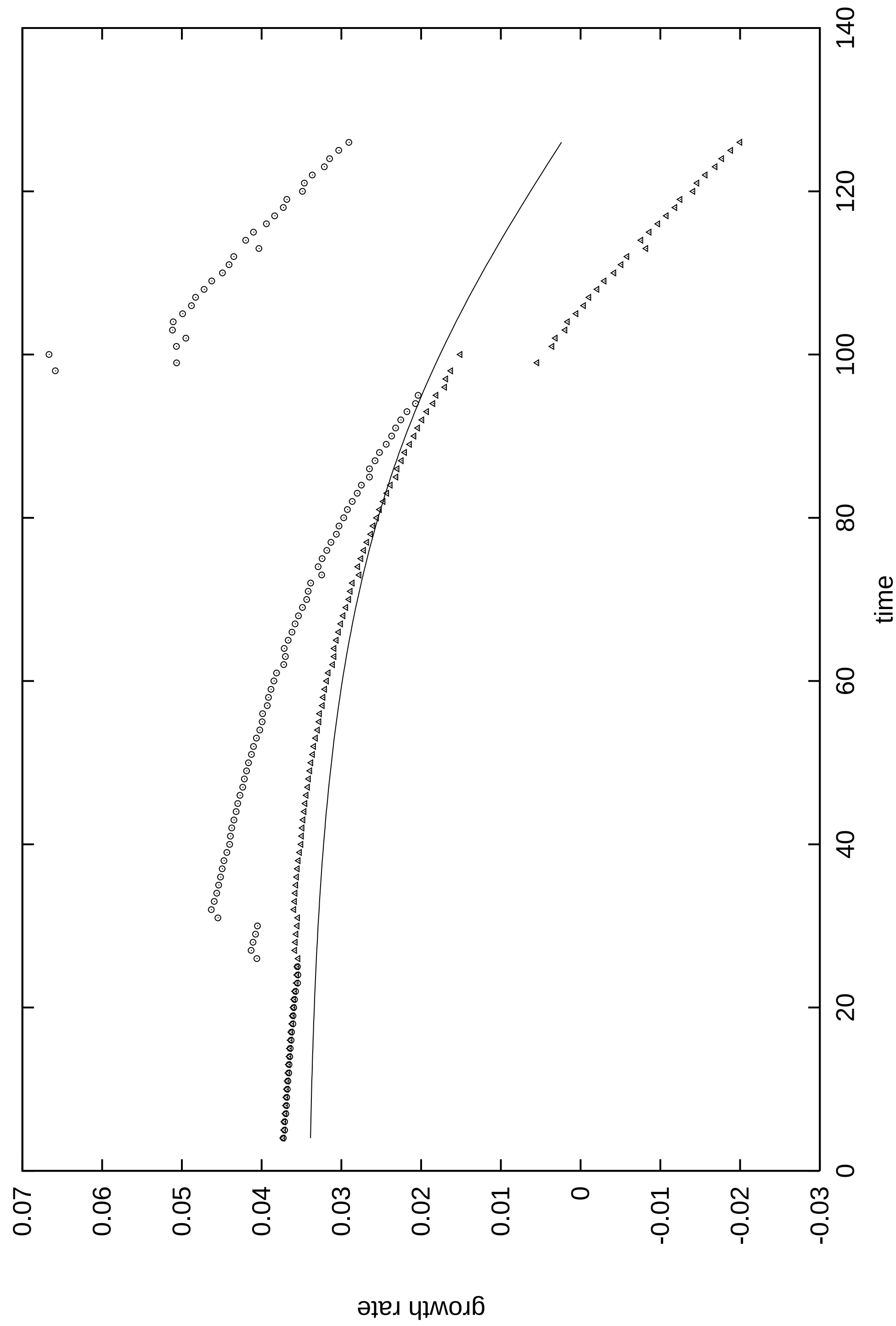

Figure 11: Representative sequence (resulting from a single simulation run) of an innovating firm's chosen partial aspiration level of growth rate $a_{G^j}^{t+1}$ ($\circ$), the firm's realized growth rates g_t^j ($\triangle$) and the minimal acceptable partial aspiration levels $\underline{a}_{G,t}$ (solid line) The initial market share of the firm is approximately 3 %.

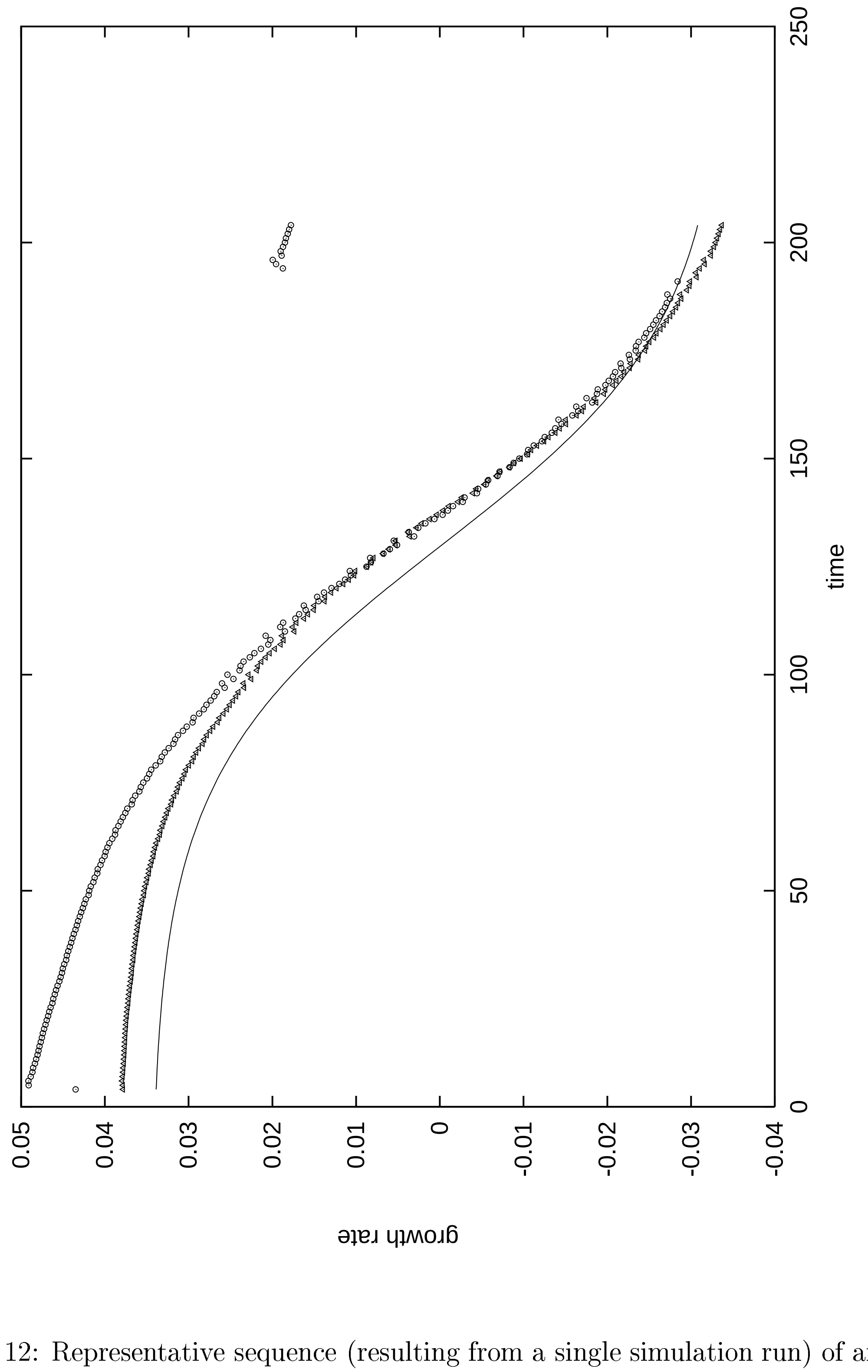

Figure 12: Representative sequence (resulting from a single simulation run) of an innovating firm's chosen partial aspiration level of growth rate $a_{G^j}^{t+1}$ ($\circ$), the firm's realized growth rates g_t^j ($\triangle$) and the minimal acceptable partial aspiration levels $\underline{a}_{G,t}$ (solid line) The initial market share of the firm is approximately 18 %.

profitability, might it start the product development without meeting that condition.

Due to increasing concentration, the growth rates of smaller firms decrease, on average, faster than those of larger firms (cf. Figure (9) and (11), (12)). This fact drives smaller firms, on average, earlier into a "growth trap" triggering the start of the development of a new product generation. Figure (13) depicts the dependence of average market share of firms starting the development of a new product generation in a given period on that period. Figures (11) and (12) show the interplay of these two effects for two representative cases of individual firm evolution.

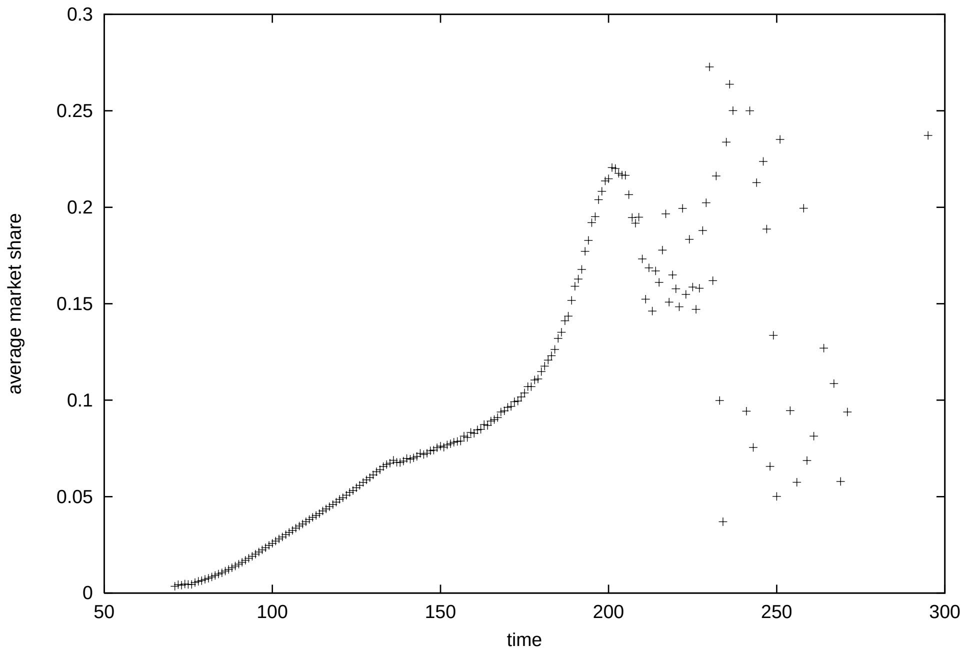

Figure 13: The average market share [%] of firms starting in a given period t the development of a new product generation (200,000 simulation runs)

To avoid results directly related to the distribution of individual firm size, we employ as a measure of innovativeness the probability of a firm being an innovator conditional on its size, rather than the unconditional probability that the innovator's size lies within some interval. To disintegrate the two effects described above we proceed as follows: In addition to the regular simulation of our model, we have run a "benchmark simulation" with all firms starting the R&D program at the same period t_{start} resulting from the regular simulation. The probability of a firm being an innovator conditional on its size obtained from the benchmark simulation (Figure (14) ($\triangle$)) reflects simply the per-period success probability function as depicted in Figure (7) while not taking into account the effect depicted in Figure (13), i.e. the delay of large firms in starting the development of a new product generation as a result of above-average performance on the market for the current product generation.

Figure (14) ($\circ$) depicts the values resulting from our model for the probability of a firm being an innovator conditional on its relative size. It follows that for firms with market share (in the period of innovation) below 0.09 the conditional probability of being an innovator dramatically increases due to the delay of larger firms in starting their development effort, and vice versa for firms above 0.09.

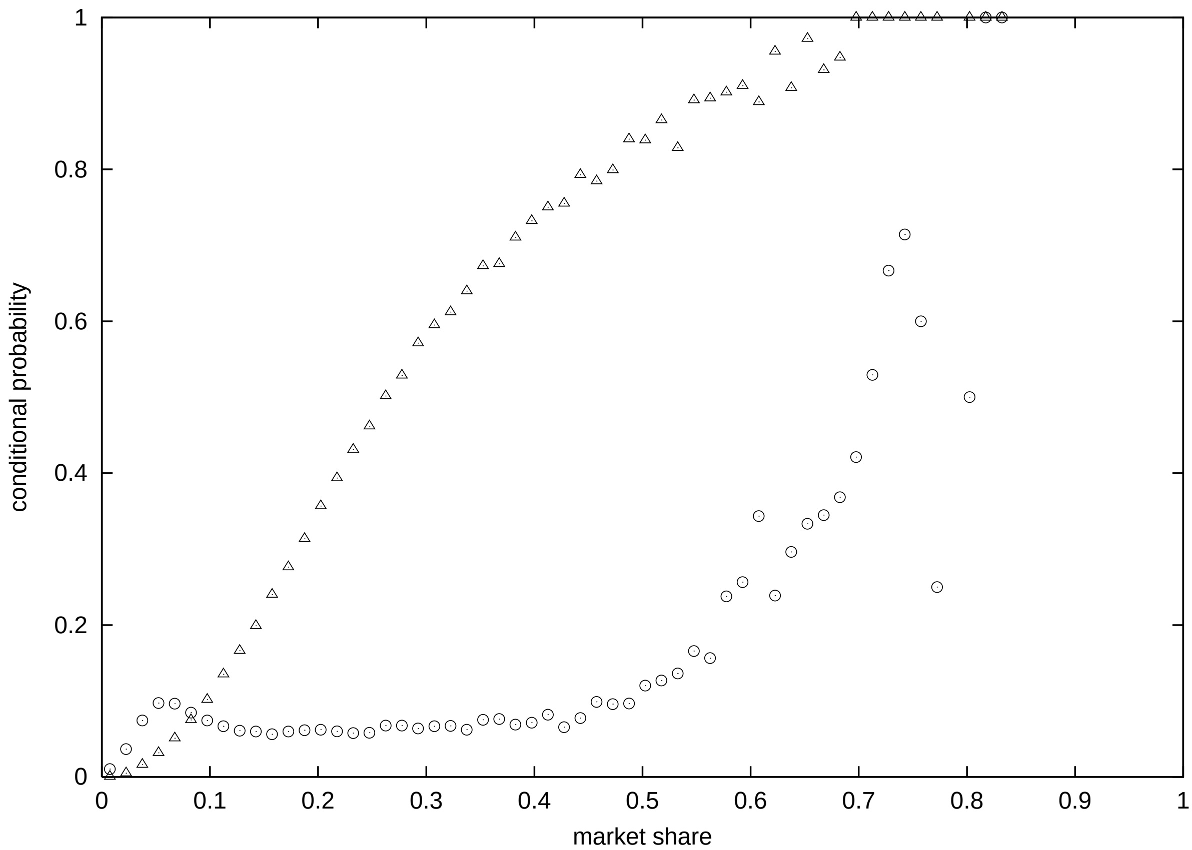

Figure 14: Individual probability of a firm being the innovator conditional on its market share in the period of innovation; the conditional probabilities resulting from a numerical analysis of the model (○) are compared with a benchmark simulation (△) in which all firms start the R&D-program at the same time (200,000 simulation runs)

5 Discussion

Based on Sauermann and Selten's (1962) aspiration adaptation theory, we propose a model of upper management's decision-making involving two incomparable goal variables, growth rate and profitability. We have argued that incomparability of the goal variables growth rate and profitability appears because members of upper management do not know how realizations of these two business performance indicators are aggregated by the evaluating institutions to produce the overall assessment of the managers' professional performance. What lies behind this uncertainty is the contention that, unlike in normative theory, evaluating institutions are not endowed with a framework relating the management's actions to the market outcome, and thus will have a subjective view on which values of profitability and growth rate should be targeted by the management.

The argument for the incomparability of goal variables is not restricted to corporate firms; rather it applies whenever external evaluation is crucial for a firm's success under the assumption that no market model is available. Consider, for instance, an owner-led firm in need for new financial resources. The capital market will then evaluate the firm's propects, again based on indicators of business performance. Thus, we have a situation analogous to the one presented in Section 2.1.

The second main hypothesis of our model is an endogenous formation of local procedural preferences based on a comparison with competitors. Indeed, Cyert and March (1992) identify "the past performance of other 'comparable' organizations" as one of three variables (besides the organization's past goal and past performance) influencing the choice of an aspiration level within an organization. In our model the performance of competitors enters into the decision process by determining the urgency order and thus indirectly the choice of the aspiration level itself.

Our framework offers an alternative perspective on the incentives for innovative activity. Rather than the expectation of future profit flows, in our model the incentive for innovative activity of a firm is an internal and external pressure to perform not beneath the average. With our particular specification of the market evolution the crisis that triggers a firm's innovative activity is due to continued substandard performance with respect to growth rate. Given the effect of increasing concentration (which itself is not explained in the paper), our model makes the prediction that larger firms will on average start the development of a new product generation later than smaller ones.

It would be interesting to extend the model to analyze the innovative activity of a diversified firm in which the management is either responsible for the innovation investment decisions of one or of several product division(s). In the latter case substandard performance in only one market will not be perceived as a crisis and thus not engender innovative activity of the firm.

Finally, we point at a basic structural aspect of the framework of aspiration adaptation with endogenous formation of local procedural preferences, namely that decision-making is described by means of models which are intrinsically dynamic. In our specific case, the actions taken by the firms will affect the market outcome, which in turn determines their local procedural preferences in the next period and, as a result, the firms' choices of their respective actions in the next period.

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