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■ *Research Paper*

Dynamics of Journal Impact Factors

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For a journal manager, boosting a journal's impact factor is an important objective. The impact factor is a measure of the frequency with which the average article in a journal is cited in a given period. The dynamics of impact factors are caused by the interplay of several concepts, such as seniority of authors and reviewers, journal policies, online availability of journals and quality of contributions. This paper's objective is to discuss three strategies to sustainably improve both a journal's impact factor and its underlying resources. To this end, a journal's assets and resources are captured in a structural simulation model, which is used for strategy experiments. The paper offers three insights: It provides a dynamic hypothesis about the causal structures underlying a journal impact factor; it highlights the fact that the levels and growth rates of the crucial resources, *authors* and *reviewers*, must be developed in dynamic correspondence. Finally, developing the stock of high-quality reviewers requires time and resources but is more stable than the stock of authors and, hence, has a higher potential for guiding the journal into a regime of sustainable development. Limitations and future paths are discussed.
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Keywords Journal impact factor; scientometrics; citations; causal model; sustainable strategy

Supporting information may be found in the online version of this article.

INTRODUCTION

Journal impact factors (JIF) have become important indicators in academia, but they are still relatively seldom discussed. A JIF is a measure of the frequency with which the average article in a journal has been cited by articles in a sample of journals during a given period. Impact factors influence major decisions both in academia and other research institutions. For instance, hiring and tenure-track decisions are based on publications in journals with high impact factors; also, research policy and grant applications are positively influenced when the track record of applicants contain top-tier journal publications.

This paper reveals the structural foundations of the dynamics of impact factors. Here, I concentrate on the widely accepted Thomson Reuters JIF® (Garfield, 1955; Garfield, 2006; Thomson Reuters, 2011). In general, the paper is written

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for an academic audience in the social sciences. In particular, it can support current and prospective journal editors in identifying strategic resources and designing policies to develop these resources. However, it is also useful for academic customers, that is, decision makers in academia who use JIF to substantiate decisions, or researchers who apply JIF to allocate their resources. Both groups can benefit from a deeper understanding of the mechanisms that result in the JIF development and how it can be influenced.

The paper demonstrates that either a successful or unsuccessful development of a JIF is not something that happens *to* a journal; rather that it is strongly *influenced by* a journal's strategy. Editorial boards, the top-management teams of journals, develop, implement and adjust these strategies and thereby pursue similar objectives as managers in profit-oriented organizations; for instance, to promote a sustainable journal development that meets the customers' demand, to increase a journal's market share or to gain a competitive advantage. Hence, a JIF becomes a performance measure of the work performed by editors and, thus, an element of their incentive system.

Given the importance of the JIF in academia, especially the Thomson Reuters JIF®, one would expect an intensive debate about its nature, effects and implications for academia as well as for the wider society. A literature review in the field of scientometrics,[1] however, did not produce the anticipated result; it shows that bibliometric research, that is, research using a set of methods to quantitatively analyse scientific literature, is rather fragmented. The current discussion concentrates on the meaning of the Thomson Reuters JIF® (Garfield, 1999, 2006), its disadvantages, possible elaborations and alternatives approaches (Moed *et al*., 1999; Bollen *et al*., 2005; Zitt and Small, 2008; Harzing and van der Wal, 2009; Vanclay, 2009; Abramo *et al*., 2010; Leydesdorff and Opthof, 2010), or the differences in magnitude of JIF in the fields of science (Althouse *et al*., 2009). Others have concentrated on the number of citations an individual paper is likely to attract over its lifetime (Mingers and Burrell, 2006). Just recently, some have addressed the emerging topics of journal self-citations (Frandsen, 2007; Yu and Wang, 2007; Andrade *et al*., 2009), an inflation of the JIF (Reedijk and Moed, 2008; Althouse *et al*., 2009; Vanclay, 2009; Krell, 2010; Neff and Olden, 2010), and the increasing use of non-citable items to push the JIF (Frandsen, 2008). The ethical responsibility of journal management has also been addressed and has culminated in the question whether editors should actively stimulate—or engineer—the impact factors of their journals (Falagas and Alexiou, 2008; Reedijk and Moed, 2008; Vanclay, 2009; Krell, 2010; Yu *et al*., 2010).

To summarize, the current research provides only piecemeal work about the origins of the impact factor dynamics. It is surprising that no work has tried to explain the underlying causes of impact factor dynamics from a structural perspective. Hence, a significant gap exists in the understanding of one of the most important yardsticks in academia. For journal editors, no guidance exists for designing strategies[2] to sustainably develop their journal in terms of rising impact factors. In this paper, a sustainable development is one that meets present needs without compromising the ability to meet future needs (WCED, 1987). Currently, journal managers have to make decisions using incomplete and subjective mental models about a complex dynamic system, which can result in unintended consequences that complicate or even prevent a sustainable development (Sterman, 1989). Examples of such consequences, for example, 'growth-and-decline' or 'stagnation' trajectories, seem to be the journals 'MIS Quarterly' or 'Administrative Science Quarterly'.

This paper tries to reduce this gap by developing a formal, systemic understanding of the dynamics of journal impact factors. It develops a dynamic simulation model that accounts for important resource accumulations and their nonlinear, delayed interdependencies (Dierickx and Cool, 1989; Davis *et al*., 2007; Harrison *et al*.,

[1] Scientometrics is the science of measuring and analysing science.

[2] Strategies are comprehensive configurations of decision rules for achieving a desirable long-term objective. A sustainable strategy here is a configuration of policies, which governs an organization so as to achieve favourable long-term outcomes as well as to provide the organization with a potent configuration of resources.

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2007; Schwaninger and Groesser, 2008; Warren, 2008). The approach facilitates experimentation with different journal strategies, which editors may implement. The model provides primary insights about the JIF's dynamics and thereby enables journal editors to experiment with different configurations of policies for designing sustainable strategies. Editors' policies are decision rules, which they implement to manage the development of their journal. In this paper, editors have four such policies at their disposal. First, the *stretch objective policy* captures the editors' decision rule to set the journal's JIF objective with respect to time. Second, the *marketing policy* expresses the editors' attention to marketing spending and effectiveness; for this, each month, a certain fraction of the available resources are invested into marketing activities. Third, the *junior reviewer training policy* states the editors' decision rule to enhance the training of junior reviewers; again, each month a certain fraction of the available resources are invested in these activities. Fourth, the *junior reviewer acquisition policy* expresses the editors' attention to gaining new junior reviewers; also here, a certain fraction of available resources is spent. Important here is that the editors have to consider policy trade-offs to manage the journal development under the condition of limited resources. The paper reports on three strategies. The first strategy, the *average-growth strategy*, corresponds to the intention of editors to achieve a modest and steady development of the JIF, which results in a development close to the average growth in JIF in a journal category. *R&D Management* seems to be an example for a journal following this strategy.[3] Editors following the second strategy, the *fast-growth strategy*, try to achieve a rapid growth in impact factor within several years. These editors intend to develop a leading journal and consider almost only marketing which is highly efficient in boosting the JIF and so have to cut back on reviewer development because of resource constraints. It seems to be successful at the outset but comes at the cost of a lower JIF in the long term and bears high risks of unsustainable resources of authors and reviewers, which this strategy does not develop. The *sustainable-growth strategy* emphasizes developing a high-quality reviewer base by means of reviewer training and acquisition, which puts the journal at a disadvantage in the medium-term. However, this improves its quality significantly and outperforms all tested strategies. Additional strategies might be alternations between the strategies I have currently tested. For instance, editors could follow a fast-growth strategy initially to boost the journal's JIF and then change to a sustainable-growth strategy. Such analysis is subject to future research.

The simulation offers two major insights: First, the levels and growth rates of the crucial resources, *authors* and *reviewers*, must be developed in dynamic correspondence. Second, developing the stock of high-quality reviewers requires time and resources but is more stable than the stock of authors and, hence, has a higher potential for guiding the journal into a regime of positive development. Given the vast dynamic complexity of the system, journal editors have to be systems thinkers to achieve sustainable results. They must wisely withstand medium-term temptations and pressures and implement strategies, which are not popular at the moment but which become beneficial later. The editors' implementation task is further complicated because they have only limited financial means available and a volatile workforce, consisting of mostly volunteer academics with heterogeneous competencies.

The paper is structured as follows: The next section introduces relevant elements of the academic journal system. Thereafter, I develop the structural model. The fourth section uses the results of computer simulations to describe and discuss three strategies. The fifth section reflects on the paper's practical and theoretical contributions as well as its limitations. The last section concludes the paper and suggests paths for future research.

JOURNAL IMPACT FACTOR AND EMPIRICAL DATA

Academic journals are the outlets of scientific research. Most relevant journals are available

[3] http://onlinelibrary.wiley.com/journal/10.1111/%28ISSN%291467-9310/homepage/ProductInformation.html.

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only as fee-based subscriptions, not as open-access publications. The online availability of journals is mostly provided by library subscriptions. Journals are ranked in categories according to their overall quality. Numerous journal rankings exist. Three important examples are: Harzing's Journal Quality List (http://www.harzing.com/jql.htm), International Scientific Journal Ranking (www.scimagojr.com) and the ISI Journal Citation Reports (http://isiknowledge.com/JCR). ISI stands for 'Institute for Scientific Information', which publishes several citation indices. Since 1992, ISI became a part of Thomson Reuters Corporation. To arrive at such a ranking, several metrics are used, one of which is journal impact factors. One such impact factor is the Thomson Reuters JIF®. For the following, assume that t stands for the current year. Then, the JIF is calculated by dividing the number of current year citations, n_t, by the source items, A, published in journal j during the previous 2 years, A_{t-1} and A_{t-2} (Equation (1)). Citeable items are types of documents that constitute the scholarly contribution of the journal to the literature and are usually articles, reviews, and proceedings papers; non-citable items are editorials, news stories, abstracts, letters-to-the-editor or book reviews (McVeigh and Mann, 2009).

$$JIF_t^j = \frac{n_t^j}{A_{t-1}^j + A_{t-2}^j} \quad (1)$$

For instance, the JIF for the *Academy of Management Journal* in the year 2009 was 6.483. This is calculated by the amount of citable items ($A_{2007+2008} = 65 + 55 = 120$), and the amount of citations of these items in 2009 ($n_{2009} = 654 + 124 = 778$). This signifies that every article in this journal published in the years 2007 and 2008 has been cited, on average, about 6.5 times by articles published in ISI journals in 2009. Other measures for the impact of journals and articles, although they have been discussed extensively (Biglu, 2008; Zitt and Small, 2008; Abramo *et al*., 2010; Leydesdorff and Opthof, 2010), have not received the same attention as the two-year JIF of Thomson Reuters. This impact factor is used in almost every field of science. A comparison between the different fields shows that its value can vary from 0.2 to 17.0. These differences stem from the degree of specialization and formalism in the field of science, different citation cultures, the number of journals and several other factors(Althouse *et al*., 2009). For this paper, I have selected the journal category 'management' because *Systems Research and Behavioral Science* is included in this category. The category covers journals on management science, organization studies, strategic planning and decision-making methods, leadership studies and total quality management. In the following, I provide empirical data about the category 'management' which are used later to parameterize the simulation model.

Subject Category 'Management'

In 2010, 4932 articles have been published in 140 management journals; the median impact factor for 2010 year was 1.221 (Thomson Reuters, 2011). Figure 1 shows the development of the JIF of five selected management journals from 1997 to 2010. One can see that the JIF assumes values from 0.6 (*Journal of Forecasting*) to around 6.8 (*Academy of Management Review*) in the year 2010 and that significant differences exist between the journals. Because the paper's objective is theory building and not theory testing (Schwaninger and Groesser, 2008), I have selected journals that represent extreme cases on both ends of the JIF-spectrum. I do not account for journals that have entered or left the subject category during the 13-year period.

The time series in Figure 1 qualitatively show patterns of exponential growth with oscillations (*Academy of Management Review*, *Strategic Management Journal*, and *Long Range Planning*) or patterns of stagnation with larger or smaller oscillations (*Administrative Science Quarterly* for the first and the *Journal of Forecasting* for the latter). My review of all journals in the category 'management' shows behaviours in the range from 'stagnating with oscillations' to 'exponential growth with oscillations'. The journal impact factors of the five selected journals show overall growth rates from 16% (*Administrative Science Quarterly*) to

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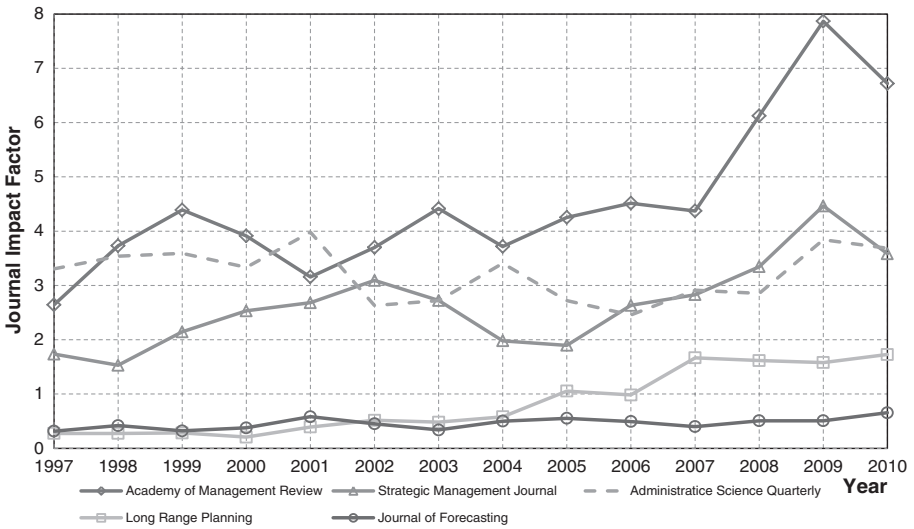


Figure 1 Journal impact factor (1997–2010) of five selected management journals

480% (*Long Range Planning*), from 1997 to 2010. Evidently, a journal impact factor is a dynamic phenomenon. However, which mechanisms generate the trajectory of an impact factor? How can journal editors support the sustainable development of their journals' impact factors? Are there likely counter-intuitive effects of policies, which might hinder a positive development? The current knowledge about journal impact factors does not allow for answering these questions. The dynamic model in the next section is a first hypothesis for addressing them and for informing the design of sustainable journal strategies.

MODEL

In the following, I develop a formal model that accounts for the relevant structure that allows one to endogenously generate the dynamics of journal impact factors. For this, I use the system dynamics methodology (Forrester, 1961; Sterman, 2000), which has been often applied in the management sciences to disentangle a system's dynamic complexity and to conduct policy analysis and design (Repenning, 2002; Black *et al.*, 2004; Sterman *et al.*, 2007; Rudolph *et al.*, 2009). I use this methodology in the theory-building mode (Harrison *et al.*, 2007; Schwaninger and Groesser, 2008).

Model Overview

To understand the dynamics of journal impact factors, a model with a broad boundary is required to capture the structural aspects that constitute the system's dynamic complexity. Hence, the model represents elements of the following agents:

- **Physical System**: The physical aspects of the system that are relevant for the JIF relate to the material flow of submitted and published articles in the respective stages of a publication and citation process (i.e. submitted articles, articles in-review, accepted article backlog, published articles and outphased articles).
- **Regulatory Institution**: The regulatory institution defines the concepts that influence the journal system and determines the ways in which JIFs are calculated. The agency is clearly represented by Thomson Reuters®, which publishes the JIF (Garfield, 1955, 2006; Thomson Reuters, 2011).
- **Journal Editors/Editorial Boards**: Editors are human agents who represent the top management teams of journals. In this function, they design the journal strategy about the JIF objective, acceptance and rejection rates, scope of the journal, the means to promote the journal and the timeliness in reviewing submitted manuscripts.

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- **Libraries**: Libraries are institutions that provide access to journals for the interested audience. Their subscriptions make the journal content available online and lead to multiplication effects of information in the system.
- **Researchers/Authors**: Researchers and authors evaluate journals and decide to write and submit their work to these journals, or not. The behavioural decisions are governed by the widely accepted academic incentive system, which includes the JIF. One assumption of this system is that the higher the JIF, the more likely will a researcher attempt to publish in this journal.
- **Reviewers/Referees**: Reviewers are researchers who support editors in reviewing and evaluating submitted articles for publication or rejection.

Model Boundary

Compared with the existing research about JIF (see Section 2), the model developed here has a broad boundary. However, even with this boundary, I had to exclude several topics. First, publishers' objectives and policies are not explicitly modelled; I assume that their interests are represented by journal editors. Second, the model does not account for different types of review processes (e.g. no substantial review, editorial review, single-blind review); a scientific review process is assumed. Third, articles under review are not differentiated in distinct rounds of reviews. Fourth, rejected articles can re-enter the article-production chain after fundamental revisions; this is not treated explicitly in the model. Fifth, the model uses the standard two-year JIF which currently seems to be the standard, which editors, authors, libraries, and universities consider in their decisions (Reedijk and Moed, 2008; Binswanger, 2010). Sixth, I assume that open-access journals will not be relevant for publishing high-quality academic work. I have decided to exclude the mentioned elements because they seem not to be crucial to understanding the dynamic complexity of the journal impact factor. Seventh, I assume that a journal has a limited amount of resources available to implement its strategy. Given the lack of data about journal-internal financial figures, I assume that the available resources are constant over the simulation time horizon; in addition, I model the limited resources using abstract resource units.

The final assumption relates to dynamic complexity. The model developed here considers one journal, *j*; other journals are treated as external. The current model is a reasonable specification under the assumption of perfect competition, that is, that journal *j's* market share is insignificant with respect to the total market; journal *j* is one of an infinite population in the same category. Consequently, *j's* strategy and objectives have no influence on the respective average values of the journal category. This assumption seems to be feasible, given that changes in the impact factor of one of the currently 140 journals in the category of management have only a small effect on the grand average. However, one might argue that leading journals, such as the *Academy of Management Review*, influence the overall journal system with their decisions. Such strong nonlinearities might exist in reality, which could require the assumption to be relaxed. Important feedback structures of the model are explained next. The complete model is available in the online appendix.

Model Structure

The most tangible elements involve the article-production chain, including their flows of citations. The article-production chain is modelled using a standard aging-chain structure (Sterman, 2000, p. 470-474; Ventana Systems, 2012). In the upper half of Figure 2, articles are submitted to journal *j*. They accumulate as articles under review in *j* until the editorial board decides about their further treatment. The model does not distinguish between immediate rejections ('desk rejection') or rejections after a substantial review by referees. Rejected articles exit the system; accepted articles accumulate in the backlog of accepted but not yet physically published articles in *j*. Most journals have an online repository, which allows accessing accepted but not yet published articles. This is an important way of increasing the availability of

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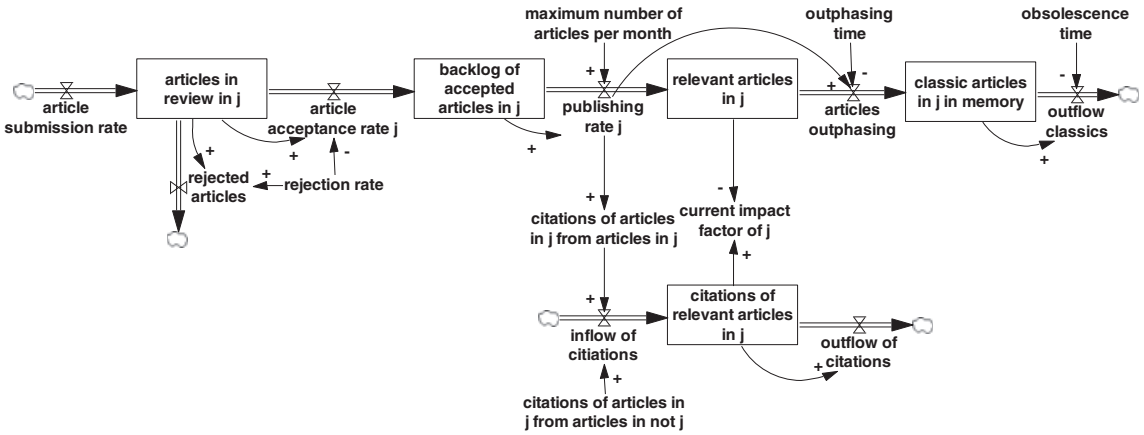


Figure 2 Article production chain (physical structure) and citation dynamics represented in a simplified system structure diagram. Note: A rectangle represents a stock or an accumulation (like water in a bathtub); flows, depicted as pipes with valves, fill or drain the stock (Sterman (2000) provides further details about the notation)

research results; however, citing repository articles does not count for the JIF because these articles are not yet published. The backlog of accepted articles is reduced by the publishing rate, which is determined by the maximum number of articles that can be published per month. After being published, the articles enter the stock *relevant articles in j* with a delay of one year and will remain in the stock for 2 years—that is, the time window during which citing the articles count for the Thomson Reuters two-year JIF®. For instance, article *x* is published in 2008; it will be relevant for citation counting in the years 2009 and 2010. The outphasing time operationalizes the two-year duration. After the articles have left the relevant time window, they accumulate as classic articles in memory, which represent the collective memory of researchers in the field. In other words, although articles do not belong to the cohort of citable articles anymore, they are still influential for the overall perception quality of journal *j*. For instance, citations of Sterman's article on 'Learning in and about Complex Systems' (1994) do not count for the JIF of the *System Dynamics Review* anymore. Nonetheless, the article is still influential—overall it has been cited more than 150 times by authors in different fields of science—and contributes to the perceived quality of that journal. After an interval of obsolescence, even these 'classic'-articles exit the memory of researchers, which might indicate, for example, either a shift in the generation of researchers or a substitution by a more recent article.

While being in the stock of relevant articles of *j*, the references to these articles are counted as citations of relevant articles in *j*. The citations can stem from two sources: citations from articles published in journals *i* (not *j*), or citations from articles published in journal *j* in the respective period. The citations to an article remain in the citations stocks for 2 years. For example, the citations of article *x* in *j*, which has been published in 2008, accumulate in the citations stock for 2009 and 2010. In the year 2011, the citations of article *x* exit the respective stock. I have modelled the citations to articles by using a traditional co-flow formulation (Sterman, 2000, p. 497-503; Ventana Systems, 2012). In the following, I introduce the decisions of editors, libraries, reviewers and authors as well as their underlying structures. Figure 3 builds on a reduced form of Figure 2 and details the agents' measures.

The first loop concerns in principle a stock-management structure (Sterman, 2000, p. 675-680; Ventana Systems, 2012) that governs the journal's rejection rate (*B1, Backlog Control*). The balancing loop intends to equilibrate the *article acceptance rate j* and the *publishing rate j*, which determine the behaviour of *backlog of accepted articles*. The rejection rate is also embedded in a second important loop, which leads to quality improvements. A

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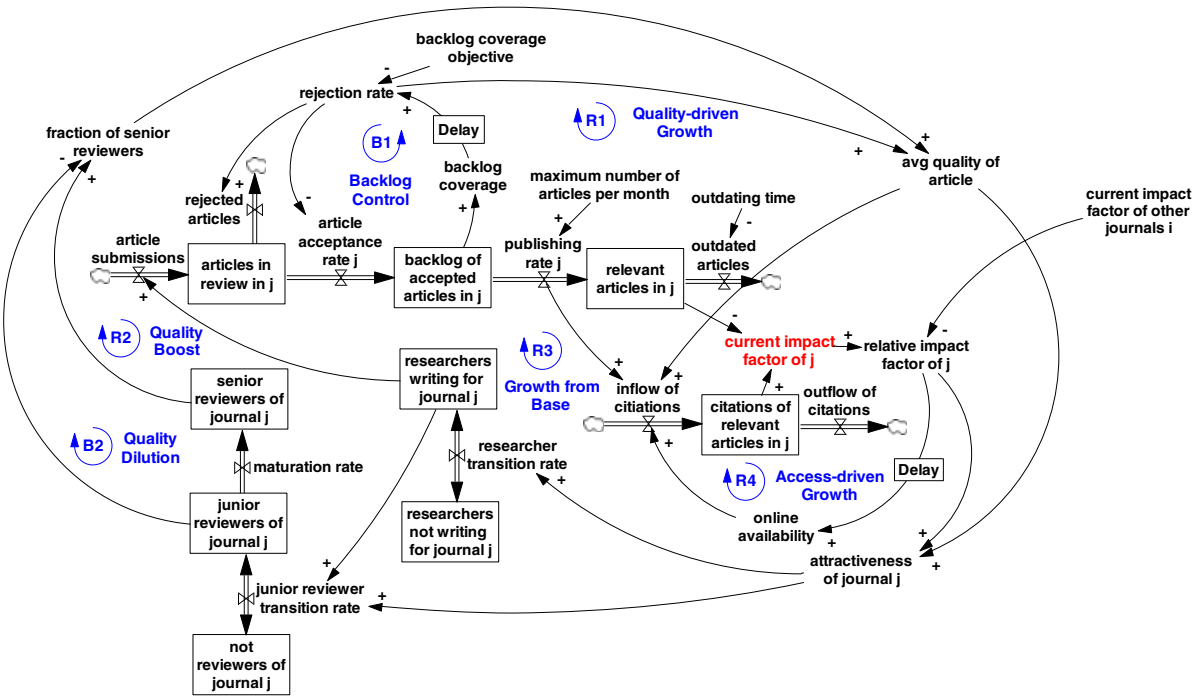


Figure 3 Physical structure and measures of authors, reviewers and libraries about the journal impact factor

higher rate of rejection results, ceteris paribus, in a higher average quality of an accepted article; the association between both variables has been modelled as an s-shaped relationship (Sterman, 2000, p. 552-562; Rogers, 2003). In turn, articles with higher quality then increase the attractiveness of journal *j*. Given the academic incentive system in the USA, the UK and increasingly also in Continental Europe, researchers are prompted to write for journals with higher quality. Hence, the higher journal *j*'s attractiveness, the more researchers want to publish in and write for *j*, which leads to more submissions. The author-transition rate follows the formulation of the adoption rate of a generic-diffusion model (Sterman, 2000, p. 300-302). *R1* is based on the rejection rate and describes a quality-driven growth process, which fuels the stock of researchers and submissions (*R1, Quality-driven Growth*). In addition, higher attractiveness of *j* also results in a higher junior reviewer transition rate for journal *j*. The reviewer-transition rate uses also the formulation of the adoption rate of a generic-diffusion model. I assume that the quality of the new reviewers is homogeneous and lower relative to the quality of *j*'s senior reviewers. I further assume that it is more feasible and easier to recruit juniors than seniors because the latter are already situated in the academic system, its disciplines and its journals, which reduce benefits and motivation for seniors to leave their current position—they are economically and emotionally locked in. At first, new reviewers lower the fraction of senior reviewers and thus lead to a dilution of the average reviewer quality (*B2, Quality Dilution*)—an aspect which has been extensively studied in project management (e.g. Abdel-Hamid, 1988; Lyneis and Ford, 2007). Over time, however, some junior reviewers gain experience, grow mature and become senior reviewers; this I have modelled by a standard aging-chain structure (Sterman, 2000, p. 470-474). The senior reviewers then contribute to increase the average quality of articles, which leads to higher journal attractiveness and over time to higher rates of submissions (*R2, Quality Boost*).

The next paragraph explains two reinforcing mechanisms having to do with the number of citations of relevant articles in *j*. The first is

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Growth from Base (*R3*). The researchers who are committed to journal *j* write for this journal. The publication of their accepted papers creates an inflow of citations of relevant articles in *j*, which increases *j's* JIF, which in turn also improves journal *j*'s impact factor relative to the current average impact factor of all other journals *i*. The metric for *relative impact factor* of *j* compares the current performance of journal *j* to the average performance of all sampled journals *i* in a specific category, for example, Management. A higher *relative-impact factor* increases attractiveness of journal *j*, which leads to even more researchers writing for *j*. I have modelled *j*'s attractiveness using the additive formulation concept (Richardson and Pugh, 1981, p. 148-152; Sterman, 2000, p. 527-528) because I assume that the effect of each input of *j*'s attractiveness is separable. The *relative-impact factor* of *j* is also used by libraries for their subscription management. Journals with higher impacts are considered more relevant in the respective field, and hence, they are included in the libraries' subscriptions. As a result, *j*'s articles are more easily available online and are cited more often. I have modelled the association between *j*'s relative-impact factor and its online availability as a s-shaped relationship. Here, the concept 'online availability' accounts for the subscriptions of libraries; it does not account for the preprint online depository of accepted articles. The mechanism described just previously I call *Growth from Base* (*R3*) because the citations to relevant articles come from researchers who are aware of journal *j* and more closely related to its field. The online availability then leads to even more citations to the relevant articles in *j* because researchers who previously have not been aware of the journal can now easily find, directly access, and cite *j's* articles (*R4*, *Access-driven Growth*).

Until now, I have introduced six mechanisms, which describe important measures of authors, reviewers and libraries (Figure 3). In the following, I introduce four measures of editors to operationalize their journal strategy (Figure 4). The first is about the *impact-factor objective of journal j* relative to journals *i*. It shows that the objective of *j* is contingent on the development of all journals *i*. The *stretch-objective policy* captures the editors' decision rule to set the objective of the journal's JIF objective with respect to time. The editors use the lever '*stretch objective of j's editors*' which influences the JIF-objective for *j*. A shortfall in the relative-impact factor of journal *j* motivates editors to take remedial actions.

A second measure is to increase the awareness of relevant research communities about journal *j* by marketing efforts, for example, reaching out to authors at conferences. These efforts likely increase the number of researchers who are aware of and author for journal *j*. The more researchers and authors who are aware of *j*, the more citations of *j*'s articles come about, which in turn increases *j*'s impact factor and lessens the short fall addressed by the editors. The mechanism *B3* describes the effect marketing has on increasing awareness (*B3, Awareness Push*). The *marketing policy* expresses the editors' attention to marketing spending and effectiveness. Each month a certain fraction of the available resources, which is defined by the policy lever '*investment fraction for marketing*', is invested into marketing activities.

Other measures relate to the development of reviewers. The third measure is about the efforts to develop the capabilities of junior reviewers. By means of advanced training workshops in reviewing, the competencies of junior reviewers can be improved, accelerating their progression to the rank of senior reviewers. This would increase the average quality of reviews and also, indirectly, the quality of articles. Consequently, the journal would become more attractive, receive more citations and, hence, would rise in its relative JIF. The mechanism 'Quality from Reviewer Training' (*B4*) helps to reduce the gap in relative impact factor of *j*. The *junior-reviewer training policy* states the editors' decision rule to enhance the training of junior reviewers. The policy lever '*investment fraction for junior-reviewer training*' defines the proportion of resources invested in junior reviewer training each month.

Regarding reviewers, a second possibility exists for influencing the current situation. Editors, perhaps supported by journal *j*'s publisher, can initiate efforts to recruit new reviewers for journal *j*. The *junior-reviewer acquisition policy* expresses

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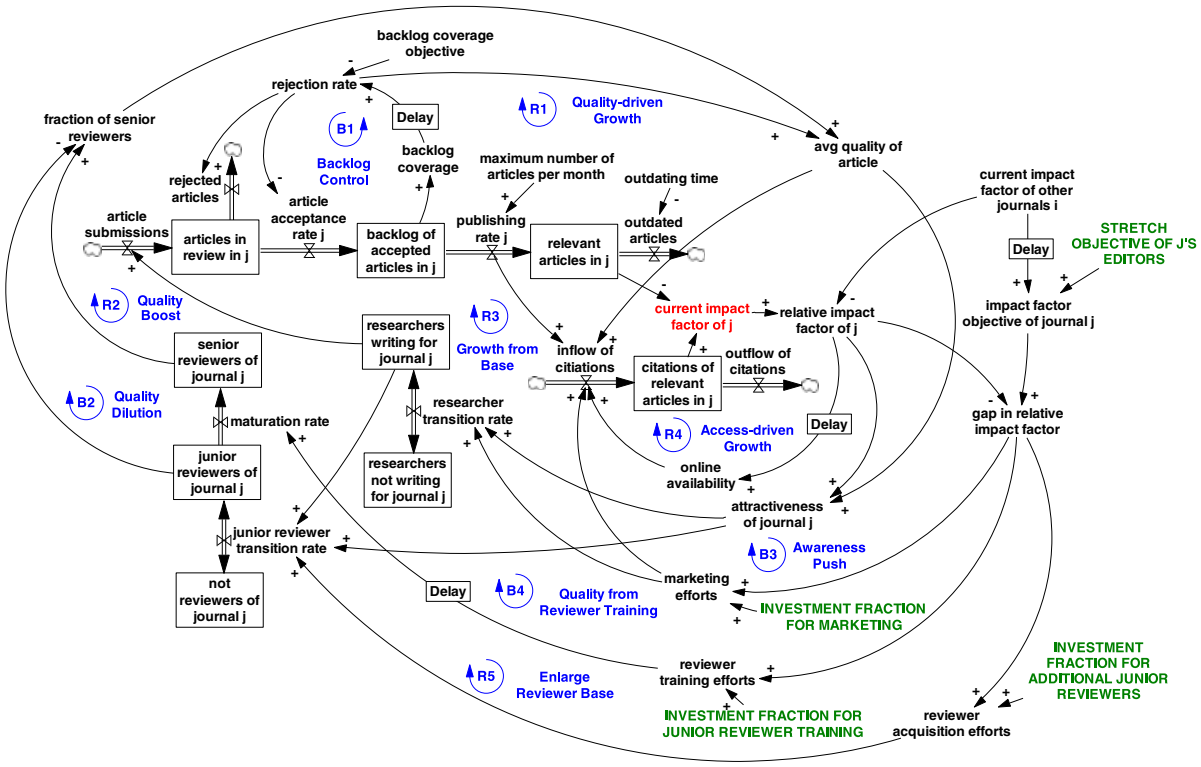


Figure 4 System structure diagram about editors' measures

the editors' attention to gain new junior reviewers. Also here, a certain fraction of available resources is spent on a monthly basis; the editors define the fraction by the policy lever '*investment fraction for additional junior reviewers*'. This measure would increase the number of new reviewers. As a result in the short-term, the average review quality and hence also the quality of papers would be reduced. If this measure would be used extensively, the attractiveness of journal *j* would decrease, its impact factor would be lower and the gap in relative journal impact would actually increase. Conceivably, this result might then lead to even further efforts to acquire additional reviewers, which would only worsen the current situation. *R5* describes a feedback mechanism that could cause counter-intuitive behaviours in the system.

Figures 2–4 have introduced the basic mechanisms as well as editors' policies and their respective levers. As has been indicated, the interrelated network of feedback loops has the potential for generating counter-intuitive and policy-resistant behaviours. The simulation experiments in the next section support designing a strategy to avoid or overcome such tendencies.

MODEL ANALYSIS

The previous section has introduced the essential model structure, which then I have parameterized, calibrated, and validated. Some of the validation efforts are documented in the appendix. To this end, I have used relevant data about journals in the ISI journal category 'management' (Thomson Reuters, 2011). The model is simulated for 240 months and is able to represent the general patterns of these journals (Figure 1) and abstracts from the short-term oscillations; here, I must also note that I do not intend to represent any one journal in particular. Rather, I use the model to carry out three strategy experiments, which I name *average-growth strategy*, *fast-growth strategy* and *sustainable-growth strategy*. Here, a strategy is

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operationalized by a specific configuration of policies. The editors can change the four policies by means of their respective policy levers, which have been introduced in Section 3 (Model Structure); the values of the policy levers are shown in Table 1.

I operationalize the resource allocation for marketing, junior-reviewer training, and junior-reviewer acquisition using a proportional split structure (Ventana Systems, 2012), which allocates the available resources according to the relative value of the policy levers, that is, the investment fractions. This standard formulation ensures that the same amount of resource is used in each simulation run and that the sum of allocations is 1. In other words, allocating more to one measure consequently limits the amounts allocated to others. However, because I do not have empirical data about the financial resources required to implement the different measures, I have used abstract units of resources. Also, because of the lack of data, I do not argue with the parameter values of the policy levers but rather with the qualitative logic represented by these values. The parameter changes are introduced at $t = 12$ (months). The simulation results are provided in Figures 5–11.

Table 1 Parameter settings for the three strategy experiments

Strategy experiment	Policy lever/parameter: Goal of strategy	Stretch objective of j's editors*	Investment fraction for marketing*	Investment fraction for junior reviewer training*	Investment fraction for additional junior reviewers*
I: Average-growth strategy	Standard strategy; growth of JIF-growth of other journals. Development of resource is not particularly emphasized.	$t = 0$: 0 $t = 240$: 0	0.39	0.22	0.39
II: Fast-growth strategy	Improve the JIF fast in the next years; become a leading journal in the field. Journal managers emphasize marketing; other resources are considered not important.	$t = 0$: 0 $t = 12$: 0.5 $t = 240$: 1.5	0.9	0.1	0
III: Sustainable-growth strategy	Editors pay attention to the journal's important resources first. Then, they focus on improving the JIF in the long-term.	$t = 0$: 0 $t = 12$: 0.2 $t = 240$: 1.5	0.33	0.27	0.4

*The policy levers are described in Section 3 (model structure).
The policy changes are introduced at $t = 12$ (months).

Average-Growth Strategy

The *average-growth strategy* supplies the base case. It represents editors who intend to match the growth in j's JIF to the growth of the average JIF in the category 'management'. In addition, the editors do not favour one specific measure but rather are relatively indifferent toward the available measures; that is, the development a journal's resources (e.g. authors and reviewers) is not particularly emphasized. The result is that *j's* impact factor develops exponentially with a low rate of growth (Figure 5), just as does the exogenous variable '*current impact factor of other journals i*'. The current impact factor of j grows by 160% until $t = 240$, which can be considered as a low-to-medium growth for a management journal (Figure 1).

Because j's impact factor develops as average, no management activities are required. The online

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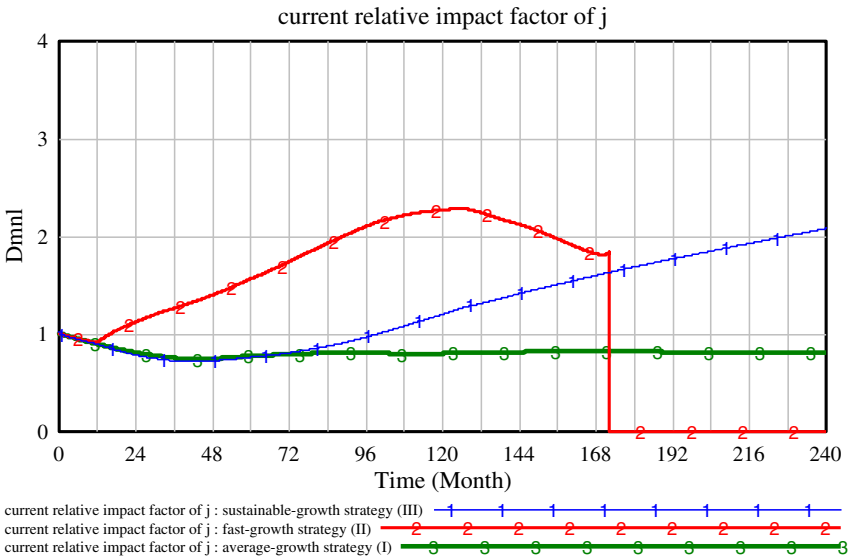


Figure 5 Time series of the impact factor of journal j

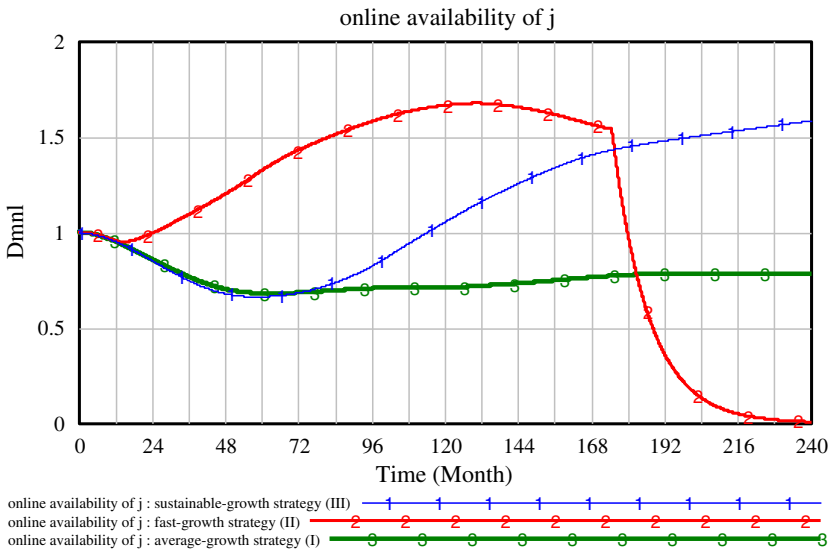


Figure 6 Online availability of journal j

availability of *j* decreases slightly and stays below unity (Figure 6). This is because libraries do not subscribe to journals with a JIF that is only average—they are biased towards journals in the upper 50% of the list. The fraction of senior reviewers oscillates around the value of 0.5 (Figure 7); the oscillation is mainly caused by changes in junior reviewers who join and leave *j* faster than seniors when the perceived attractiveness of *j* changes. In addition, the ratio of authors and reviewers increases constantly to a value of up to 5 [dmnl] and above (Figure 10). *J*'s attractiveness alternates because of complex interactions among the perceived quality of articles in *j*, its

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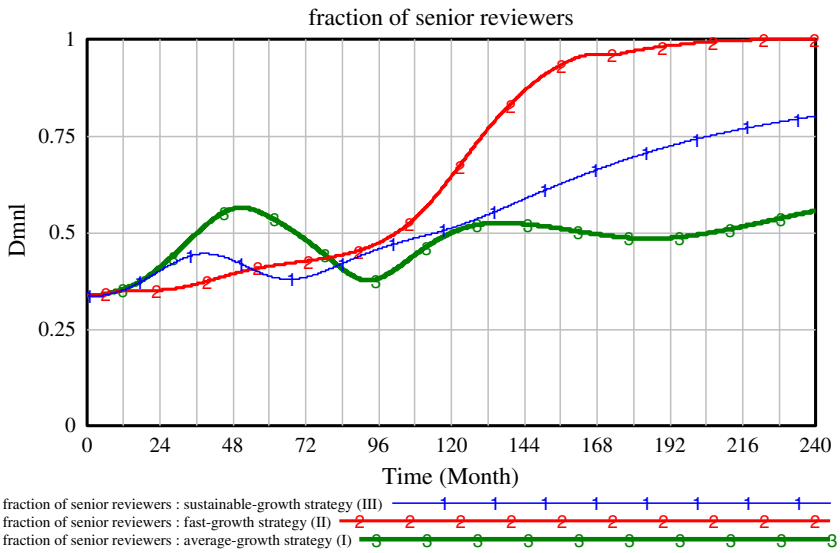


Figure 7 Fraction of senior reviewers for all three strategies

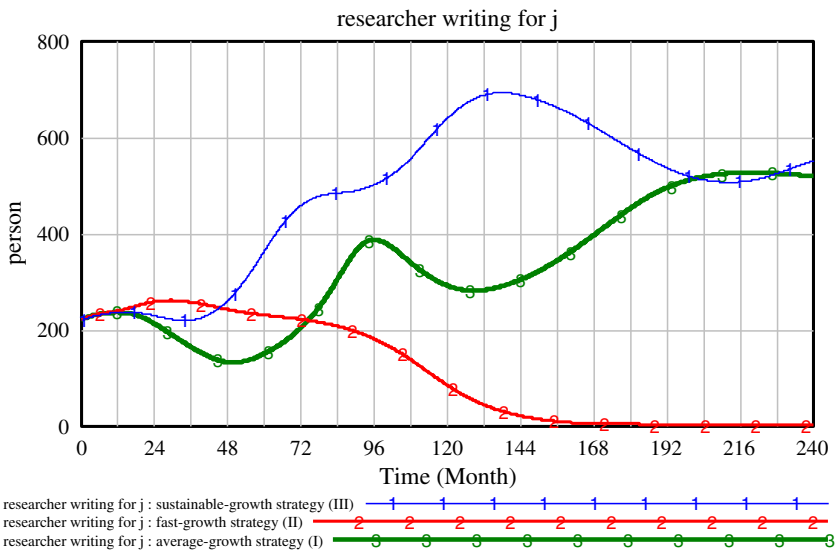


Figure 8 Researchers writing for journal j

online availability, the gap in impact factor of *j* relative to *i* and other factors (Figure 4). In this average-growth case, the attractiveness of *j* causes the number of authors writing for *j* roughly to triple within 20 years (Figure 8). Also, the average quality of published articles increases over time because of improvements in the reviewer stock, more submissions, and higher rejection rates. The oscillations in quality stem from fluctuations in the stocks of senior and junior reviewers. The computed time series, for both the resources and resource-related properties, indicate the base case and are used to evaluate the outcome of the two other strategies.

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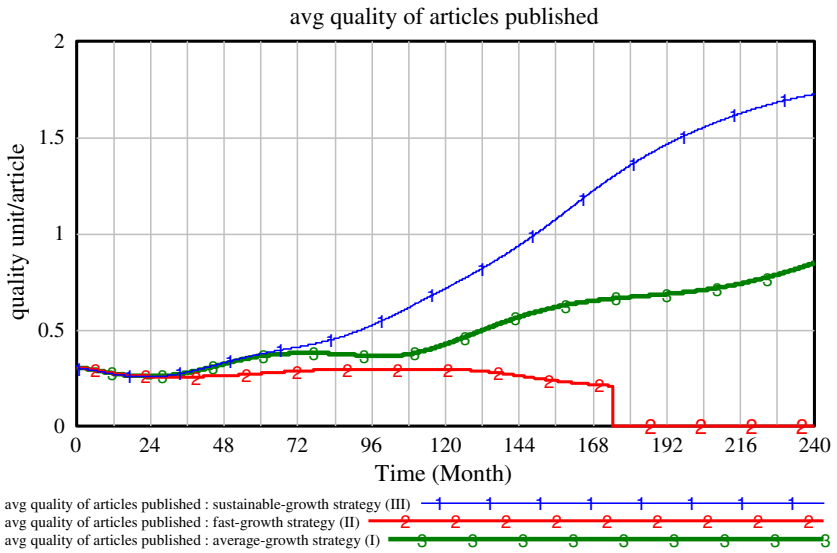


Figure 9 Average quality of articles published

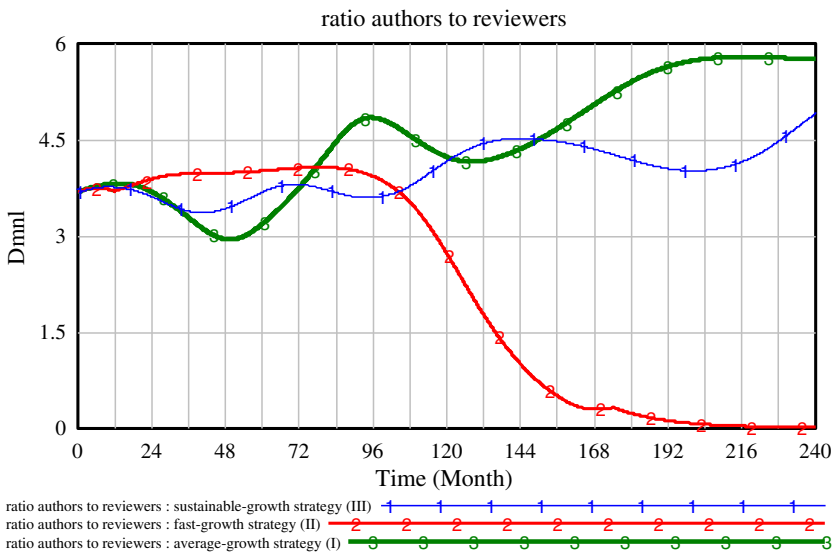


Figure 10 Ratio of authors and reviewers

Fast-Growth Strategy

Editors following the *fast-growth strategy* intend to develop a leading journal in the field of management with respect to the JIF in a short amount of time. The journal managers' mental models suggest that marketing (*Awareness Push, B3*; Figure 4) is the primary means to achieve a high JIF in a short time span. Such reasoning goes on to maintain that with increased awareness of *j*, there is no need to spend scarce financial and time resources to develop reviewers' competences and reviewer capacity—the assumption is that reviewers are attracted to the journal by

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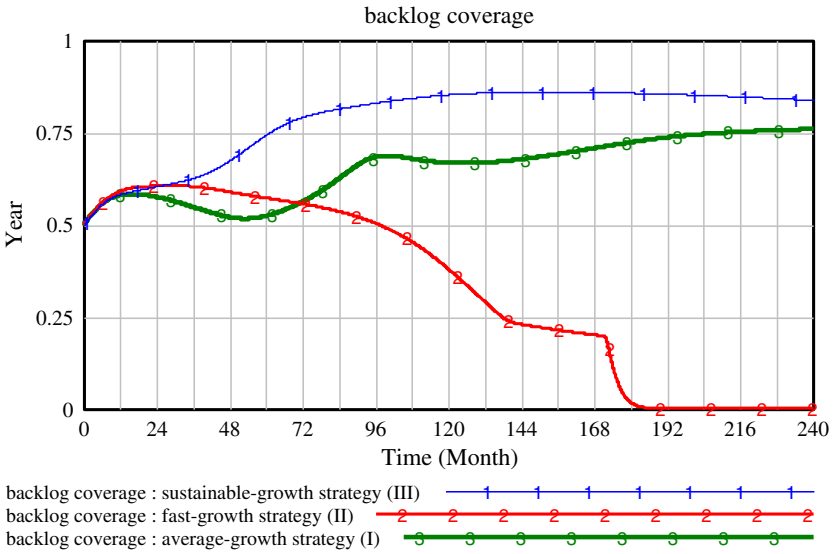


Figure 11 Backlog coverage and average publication time as performance measure for journal j

the increased impact factor alone. In addition, the editors set the following aggressive objective: *j*'s JIF has to outperform the average journal by 50%, starting at $t = 12$, and should expand this advantage to 150% at $t = 240$ (Table 1).

Based on intensive marketing efforts, *j* becomes more widely recognized, with the consequence that the impact factor increases rapidly during the months immediately following the change in strategy. In month $t = 122$, however, growth stalls and the JIF is even reduced thereafter with a devastating event around $t = 170$: the editors and the publisher of *j* decide to discontinue the journal because the backlog of articles is below a critical threshold. Consequently, *j* is not included in the list of ISI-ranked journals anymore. The significant initial growth in JIF cannot be sustained in the long-term because the emphasis on marketing leads to additional authors who submit to *j* but whose submissions cannot be managed appropriately because reviewing capacity does not grow accordingly (see ratio of authors and reviewers, Figure 10). In fact, the reduced emphasis on developing junior reviewers does not account for the retirement of senior reviewers, with the result that the stock of senior reviewers dries up. Consequently, the average quality of *j*'s articles cannot be sustained, given that the capacity of senior reviewers is stretched to its maximum. It takes significant time until the loss in quality becomes obvious (Figure 9) because of the backlog of accepted articles and their publication. This loss in quality is amplified by *R1*, which acts now as a vicious cycle: authors stop writing, and junior reviewers cease reviewing for journal *j*. The submission rate then stalls, which moves the editors to reduce the rejection rate, which in turn lowers the average quality of the articles even more, with a consequent even lower attractiveness of *j*; *R1* destroys both *j*'s quality and its impact factor.

The online availability of *j* is relatively high in the first years; libraries subscribe to *j* because of the marketing efforts. However, this does not translate into sustainable resources, for example, a stock of highly capable reviewers. Although junior reviewers are attracted to *j* at the beginning, with the result that the fraction of senior reviewers stays at a lower level than in the base case, the under-supported measure for reviewer development does not use this advantage to develop senior reviewers. With lower impact factors, junior reviewers quickly cease reviewing for *j*, leaving only senior reviewers to manage the submissions, with the result that the fraction of senior reviewers approaches the value of [1]

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(Figure 7).[4] With an overtaxed reviewer stock, the journal quality stalls, leading more reviewers to leave. At the end of this development, the fraction of senior reviewers is almost at unity—indicating an unsustainable condition. In addition, the diminishing JIF leads to losses among authors. Around $t = 170$, the journal ceased to exist (Figure 5); accordingly, the average quality of newly published articles in *j* drops to [0] (Figure 9).[5]

Sustainable-Growth Strategy

Suppose that other journal editors emphasize investing more in a journal's resources and less in marketing efforts (Table 1). The *sustainable-growth strategy* is based on the assumption that improving reviewer quality will merit rewards in due time. Also, the editors initially set the JIF objective for *j* lower than the JIF objective of the *fast-growth strategy*: an increase by 20% at $t = 12$, which ought to grow to 150% at $t = 240$. The strategy could be paraphrased as developing a journal's important resources first, then focusing on improving the JIF in the long-term.

Based on this strategy, libraries initially include *j* less often in their subscriptions compared with the other cases; thus, its online availability is lower. This situation changes around $t = 173$ (Figure 6): investments in reviewer quality, which lag significantly in their effects because of publication delays and article backlog, results in a high average level of quality of *j*'s articles (Figure 9). With this, the articles are more often cited, which helps to improve *j*'s impact factor. Initially, the fraction of senior reviewers is higher (Figure 7); the ratio of authors and reviewers (Figure 10) is lower than in the case of the *fast-growth strategy*. However, the continuous investments in increasing as well as enhancing the reviewer stock result in a competent reviewer base, yielding high-quality articles which, in turn, attract further authors to *j*. The virtuous cycle *R1* (Figure 4) helps to grow the journal's impact factor over time. This results approximately in a threefold increase in author base and a sixfold increase in average quality within 20 years.

DISCUSSION

Evaluation of Strategies

Three strategies have been described. When evaluating them, one has to specify the relevant time horizon. Here, I distinguish two, 'shorter than 10 years' and 'longer than 10 years'. Given the time constants in the publication system, for example, for review and publication, this differentiation seems reasonable. The *fast-growth strategy* is superior in developing the JIF in the first time horizon, and the *sustainable-growth strategy* in the longer one. However, evaluating a strategy based only on the JIF might be too narrow. It is also important to account for the resources that underlie the outcome variable (Wernerfelt, 1984, 2010; Barney, 1996). For academic journals, some of the important resources are the fraction of senior reviewers, the stock of authors, the online availability of the journal and the average quality of the articles. When the two strategies are evaluated with regard to these resources, then, interestingly, the *sustainable-growth strategy* is clearly superior across *both* time horizons. It maintains a significantly higher average article quality, a larger stock of authors and a more balanced fraction of senior reviewers. Although the *fast-growth strategy* has the advantages gained by pushing the JIF, it achieves them at the expense of both available and potential resources. Moreover, a relevant performance measure for a journal is the backlog coverage. Figure 11 shows the development of the backlog coverage for the three strategies. The *sustainable-growth strategy* is able to develop a beneficial backlog coverage of about 0.8 (years), which is slightly

[4] The exit rate of senior reviewers is considerably lower than the one for junior reviewers. This means that, although the stock of senior reviewers is also declining and reaches a value of [0] in the long-term, the fraction of seniors increases in the mid-term.

[5] The variable 'relevant articles in *j*'represents the articles in *j*, that, if cited, count to the journal *j*'s impact factor. In case of the Thomson Reuters two-year JIF®, articles are in the stage of being relevant articles for 2 years. The discrete change in the average quality of these relevant articles is caused by the editors' decision to discontinue journal *j*. In case the journal is discontinued, it will be excluded from the Thomson Reuters JIF.

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higher than for the *average-growth strategy*. The *fast-growth strategy* cannot sustain the initial backlog coverage level. In fact, this strategy reduces backlog of articles steadily until the journal has to cease (Figure 11).

To summarize, strategy evaluation depends on the time horizon and the focus of the beholder: If a medium-term horizon with a concentration on the JIF is assumed, then the *fast-growth strategy* seems to be the one to choose, at the expense of a degraded journal resource base. However, if the beholder assumes a more comprehensive as well as long-term perspective, the *sustainable-growth strategy* is preferable. This qualitative insight about the strategic orientation of a journal is relatively independent from the specific parameter values chosen for the policy levers. Univariate and multivariate sensitivity analyses demonstrate the robustness of the described behaviour patterns for *j*'s JIF while varying systematically the parameter values of the policy levers (the documentation of some sensitivity analyses is provided in the online appendix due to space restrictions). The three ranges that could be identified under extreme parameter variations correspond to the resulting behaviour patterns of the three strategies the paper has demonstrated.

Theoretical Discussion

On a more abstract level, the editors of a journal must account for the fact that journal quality is influenced by authors and reviewers. From a management perspective, both of these resources must be managed in dynamic balance with each other. A disequilibrium between them results in either lower quality or longer review times and, hence, in lower impacts. The fundamental management task is therefore dynamically to control the adequate relation of authors to reviewers, especially their respective rates of growth. That is a challenging task because the stock of authors is more dynamic compared with the stock of reviewers. The first can be increased faster but also can suffer a higher attrition rate; the second imposes longer delays and follows a more nonlinear behaviour. The control of such a heterogeneous dynamic system becomes an overwhelming task for humans (Dörner, 1980; Sterman, 1989; Kluge, 2008). Because of this, journal managers, in principle, face the same challenges of bounded rationality, misperception of delays and feedback as industrial mangers do (Ford, 1990; Paich and Sterman, 1993; Sterman *et al*., 2007). This paper has helped to carve out and make visible the different dynamics of those stocks that are relevant for the evolution of a JIF; future research needs to test these dynamic relationships empirically.

Implications for Practice

Based on discussions with several journal editors, it seems to me that the practice of journal management is underdeveloped. For instance, it seems that the strategic direction of journals is often not discussed by the editorial board. This is particularly noteworthy because the initial direction taken by a journal's strategy has the potential to significantly alter the development trajectory of a journal's important resources. This might even lead to the phenomenon of path dependency, which would strongly reduce future strategic options of journal development.

Based on the paper's findings, several areas of journal management would seem to require editors' attention. First, the editors of a specific journal need to discuss their important resources and resource-related properties and reach a consensus about them. Second, the development of a resource monitoring and controlling system is helpful in accounting systematically for the stocks of reviewers and authors. For both stocks, especially their growth rates, the quality and frequency of both reviewing tasks and submissions would have to be monitored, and an integrated development process would have to be designed for strategically developing both resources. Third, explicit discussions about important policies are necessary, for example, the rejection rate, the importance of marketing, and the approach to reviewer development because they operationalize a journal's strategy.

Beyond that, the following topics would also merit scrutiny: the projected time horizon and the journal's strategic objective. The simulation

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model developed in this paper could inform such a discussion. In view of the three implications for practice outlined above, the management of a journal is a full-time profession rather than a voluntary part-time endeavour. Currently, only a few management journals have full-time staff dedicated to journal management; my hypothesis is that a journal's overall quality and impact factor strongly depends on the full-time employment of its editors.

Limitations

This paper has several limitations. The first is its definition of sustainability. I base the idea of a *sustainable-growth strategy* on the notion of sustainable development, which the paper tries to operationalize from a resource-based perspective. This operationalization might be open to discussion. Second, the general trends of exponential growth, equilibrium, or stagnation could be generated with a much simpler, even a one-stock model (Sterman, 2000). However, a simpler model would be unable to provide the same insights about the system structure and its dynamics as the policy model developed here. Only the concreteness of the model shows us that the dynamic balance between authors and reviewers is crucially important for developing the JIF. Third, there exist still further options for influencing a journal's impact factor. For instance, the timing in publishing influential papers: The earlier a paper of highest quality is published in the running year, the more citations it will receive (Falagas and Alexiou, 2008); the later in the year the same paper is published, the shorter the time available for developing its impact and collecting citations. Also, another timing-related measure is the end-of-year editorial summaries of publications for the year then ending, which lead to additional citations. Also, not considered here are new types of manuscript, which might count as citable items (see Reedijk and Moed, 2008). Finally, the possibility of changing the number of issues and articles, which a journal can publish in a given year, is also not taken up here. The paper in its current version has developed a model, which is versatile enough to include these measures, which I have just mentioned. Future research would have to integrate the measures as well as the likely unintended consequences in case they are applied. For instance, in case editors extensively motivate current authors to cite articles of their own journal more often, this results in a higher JIF and also a higher self-citation rate. Because of this, the current scientific discussions about self-citation rates might gain momentum, which in turn might result in a tendency to degrade journals with a high self-citation rate. Based on the experience gained by extensive experimentations with the simulation model, I assume that the fundamental author and reviewer dynamics and their dynamic correspondences remain intact even when additional measures are applied. To summarize, although several limitations apply, the paper delivers insights into dynamics that pertain to both theory and practice.

CONCLUSIONS

The currency of today's academic market is publications in top-ranked journals. Rankings of journals and their impact factors are important signals of academic quality, which influence resource allocation in academia. Because journals compete in the academic arena for recognition, journal impact factors have become an element in the structural fabric of the academia. Despite extensive research about journal impact factors, their shortcomings and the possible ways of reducing these shortcomings, no integrated structural understanding of the system underlying the dynamics of impact factors is available. This paper provides a first dynamic hypothesis designed to close this gap. This hypothesis is operationalized as a system dynamics simulation model with a broad model boundary that integrates multiple groups of agents, for example, editors, libraries, authors and reviewers. The model is used to experiment with, analyse, and design different growth strategies for journals. Besides formulating a base case, the paper reports on two other strategies. The *fast-growth strategy* has been defined to quickly increase the JIF. This strategy is

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successful only when the journal's objective focuses exclusively on the JIF and only over the medium-term. Following this strategy, the JIF enjoys a boost during the first 10 years. This strong and fast increase is achieved at the expense, however, of underlying resources, which are decimated. Alternatively, the *sustainable-growth strategy* is successful if the journal management assumes a comprehensive definition of their objective—that is, not only boosting the JIF but also developing and sustaining the journal's significant resources. Given this broad understanding of goals and means, the *sustainable-growth strategy* is superior over the medium-term and also the long-term and finally outperforms the *fast-growth strategy*.

Comparing the simulation experiments results in two major insights: first, the levels and growth rates of the crucial resources, *authors* and *reviewers*, must be developed in dynamic correspondence. Second, developing the stock of high-quality reviewers requires time and resources, but the stock growth is more stable than the stock of authors and hence has a higher potential for guiding the journal into a regime of positive development. The dynamic hypothesis developed in the paper is a further contribution. It demonstrates a first step towards formalizing the underlying mechanisms of journal impact factors and providing insights into their dynamics. With this step, a significant gap in the literature has begun to close.

The paper opens up also several avenues for future research. One would base the model analysis on a single specific and insightful case study, for which the historical behaviour would be numerically available. With those factors in hand, an empirical test of the dynamic hypothesis developed in this paper would become feasible. Another avenue would be to use different impact algorithms, for example, the five-year journal impact factor or the Eigenfactor (Harzing and van der Wal, 2009) or the Eigenfactor™ (Zitt and Small, 2008; Zitt, 2010) and to compare their outcomes when using the different strategies. Final avenues might be to account for other disciplines than management or to integrate additional concepts into the formal model, for example, self-citation or scientific research networks.

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