MODELING THE DYNAMICS OF ACADEMIC PUBLICATIONS AND CITATIONS

by

Nisa Önsel

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APPROVED BY:

Prof. Yaman Barlas ....
(Thesis Supervisor)

Assoc. Prof. Necati Aras ....

Assoc. Prof. Ali Kerem Saysel ....

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ABSTRACT

MODELING THE DYNAMICS OF ACADEMIC PUBLICATIONS AND CITATIONS

Publication performance of researchers in scientific institutions is evaluated with some performance criteria for purposes like promotion, tenure or funding decisions. However, there is a common concern that measuring research performance, if not properly done, may damage science. Researchers tend to change their research practices when they are asked to be good at some particular measure. In this study, a dynamic simulation model is developed for analyzing the change in publication practices of researchers towards improving the performance measures used. Reputation of the faculty, skill level, total time devoted to research activities, acceptance fraction of the papers by the journals, publication and citation pressure on the researchers are the basic variables in the model. The model is constructed and calibrated using Boğaziçi University Engineering Faculty data. The validation of the model is established by standard structure and behavior tests. Scenario and policy analysis are performed with the simulation model to find good policies, which will carry the engineering school to a better position in academic world, while not damaging the scientific work of researchers.

Forcing researchers to publish in high numbers results in numerous spurious publications with lower citations. Upgrading standards by introducing high benchmarks makes researchers increase the time that they devote to research activities. Allowing researchers spend more time on research activities by easing their loads is found to be an effective managerial policy. Surprisingly, encouraging the faculty to give more internal citations provides a high reputation for the school in the end and thanks to high reputation level, both citation receiving rates and publication production performances improve. Encouraging mostly the high quality research is found to be a good policy, by generating more high quality publications compared to low quality ones,

hence increased citations.

ÖZET

AKADEMİK YAYIN VE ATIFLARIN DİNAMİĞİNİN MODELLENMESİ

Akademik yükseltme ve "tenure" kararlarında ve akademik çalışmalara ödenek ayırmak gibi amaçlarla bilim insanlarının yayın performansları çeşitli peformans ölçütleriyle değerlendirilir. Ancak, yayın performansının ölçülmesinin doğru yapılmadığı takdirde bunun bilime zarar verebileceği, yaygın bir endişedir. Yayınları bazı ölçütler ile değerlendirilen bilim insanları, akademik çalışmalarını o ölçekler doğrultusunda değiştirme eğilimindedirler. Bu çalışmada, performans ölçme kriterlerine göre bilim insanlarının akademik çalışmalarını nasıl değiştirdiklerini gözlemlemek üzere dinamik bir simülasyon modeli kurulmuştur. Modeldeki temel değişkenler bilim insanlarının ünü, yetkinlikleri, araştırma faaliyetlerine ayırdıkları toplam zaman, yayın gönderdikleri dergilerden kabul alma olasılıkları ve bilim insanları üzerindeki yayın baskısı ve atıf baskısıdır. Model, Boğaziçi Üniversitesi Mühendislik Fakültesi verileri kullanılarak kalibre edilmiştir. Modelin validasyonu standart yapısal ve davranışsal doğrulama testleri ile sağlanmıştır. Senaryo ve politika analizleri ile, bilim insanlarının akademik çalışmalarına zarar vermeden, Fakültenin akademik performansını arttıracak politikalar aranmıştır.

Akademsiyenleri çok sayıda yayın yapmaya zorlamak, kaliteli olmayan ve az sayıda atıf alan yayınlardan oluşan, anlamsız bir yayın envanterine neden olmaktadır. Yayın performansının kıyaslandıgı standardın yükseltilmesi, bilim insanlarının araştırmaya ayırdıkları zamanı arttırmalarını sağlamaktadır. Bilim insanlarının idari ve eğitimle ilgili yüklerini azaltıp onlara akademik çalışmalar için daha serbest zamanlar sağlamak da yayın ve atıf performansını arttırmaktadır. Bilim insanlarını yayın yaparken birbirlerine kurum içi atıf yapmaya teşvik etmek, uzun vadede fakültenin ününü arttırmakta, ve artan ün sayesinde atıf alma oranı ve yıllık yayın sayıları artmaktadır.

Son olarak, kaliteli çalışmaların teşvik edildiği, yayın sayısının çokluğunun dikkate alınmadığı bir politika denenmiş, ve çok atıf alan kaliteli yayınların artan sayılarda yapıldığı gözlenmiştir.

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1. INTRODUCTION

“Measuring and analyzing science” has emerged as a new field of science recently. Different names have been assigned to this science all of which dealing with the different aspects of the field (Hood, 2001). The terms bibliometrics, scientometrics and informetrics are coined respectively over time. Bibliometric methods have been applied in various forms for more than a century, indeed (Pritchard & Wittig, 1981). However, it is after 1960s that this “science of measuring and analyzing science” phenomenon has become a very hot topic among scientists.

Pritchard (1969b, p. 348) defined bibliometrics to be “the application of mathematical and statistical methods to books and other media of communication”. In 1969, Vassily V. Nalimov & Z. M. Mulchenko coined the term ‘scientometrics’ (Nalimov & Mulchenko, 1969b). Scientometrics has typically been defined as the “quantitative study of science and technology” (Van Raan ,1998, p. 5). What makes scientometrics different than bibliometrics is explained by Wilson (2001) as, while bibliometrics only measures and analyzes the literature output like publications and citations in number, scientometrics measures and analyzes much more, like the practices of researchers, the socio-organizational structures, research and development management, the role of science and technology in the national economy, governmental policies towards science and technology, and so on (Wilson, 2001). The most recent metric term ‘informetrics’ was proposed in 1979 by Nacke with a definition covering the domain of both scientometrics and bibliometrics (Nacke, 1979).

Although the three ‘measuring science/information’ fields are defined to measure different aspects of science and scientific outputs, they all emerged because of similar concerns, which can be summarized as the necessity for measuring the performance in academic work objectively. The greatest effort has been expended on finding compact quantitative formulas as research performance measures. There have been numerous attempts for inventing such performance measures and there are already many variants in use. Tenure committees need the performance measures for tenure decisions and promotions. Funding organizations need them for determining the amount of fund to be assigned to a particular university. Performance measures are also necessary to be able to compare the performances of countries, universities, research groups, or even individual researchers and to get an idea of the reputation of researchers.

Researchers who study the above-mentioned metric sciences first counted the number of publications. When the fact that number of publications does not provide an indication about quality was realized, number of citations was included in the analysis of science. (Garfield, 1970) To be able to measure the research performance of individual scientists, citation-publication balancing metrics like h-index, g-index etc. have been introduced to academic world. Currently, there are different procedures applied in different countries for measuring research performance.

Since 1986, higher education institutes receiving funding from UK Higher Education Funding Councils have been subjected to Research Assessment Exercise (RAE) on a regular basis (Moed, 2008). Over 90 percent of the Funding Councils' research grant to universities is determined by the RAE results (Barker, 2007). Barker (2007) shortly defines RAE as a periodic national peer review organized by 'units of assessment', which broadly relate to disciplines or subject areas (Barker, 2007).

In Australia, for more than a decade, a large part of the government funds that support the research activities is allocated on the basis of formula that comprise three elements: research income, postgraduate students, and publications (Butler, 2004).

Norway introduced a new performance-based funding model in 2002. The model aims to improve education as measured by the credits and graduates produced, increase research as measured by research publications, and enhance external relevance as measured by external funding. (Frolic, 2006)

In Netherlands, The Center for Science and Technology which studies at Leiden University developed a series of new bibliometric methodologies. The results of the research evaluation are used by Organization of Universities in the Netherlands and

The Netherlands Organization for Scientific Research. (Moed, 2005, s. 29-30)

In Canada, the director of C.H.U.L research center at the University of Laval in Quebec apportions resources and promotions in the lab on the basis of a grading system in which the size of a researcher's grants counts for 40 percent, the performance of graduate students and postdocs for 20 percent, and citations impact for the remaining 40 percent. (Taubes, 1993)

In Turkey, there is not a formula or a model by which universities receive funding from government. The necessity for performance measures appears in promotion and tenure decisions. The minimum performance standards to be hired by a university or to be tenured are determined by Yüksek Öğretim Kurulu (YÖK). Besides the standards of YÖK, universities define their own standards. In the recent years, a minimum number for number of publications is specified. To be counted, the publications should be published in journals that are peer-reviewed and covered by ISI.

Peer review, research income, performance of postgraduate students, publications and citation impact are the main performance measures used by countries mentioned. The source of absence of consensus is the complexity of the issue. Every indicator has its pluses and minuses. Inventing a compact, single performance measure is not an easy job.

Including citation impact in research performance measurement is based on the belief that citation is a medium for communication of research results. A controversial debate is going on about what citations measure.

In 1979, Garfield claimed that act of citing is an expression of the importance of the cited material because, authors refer to previous material to support, illustrate or elaborate on a particular point. He considers the total number of such expressions the most objective measure of the material's importance to current research. He adds that number of times all the material in a given journal has been cited is an equally objective and enlightening measure of the quality of the journal (Garfield, 1979, p.24).

Moed (2005, s.202) points out that citation analysis is a very good measure of the quality of scientific work to be used in sociological studies of science. However, he adds that it is not perfect and not for individual decisions (Moed, 2005, s. 202). There are some technical complaints on the citation issue like self-citation, negative citation, the type of the publication and the size of the units being evaluated. The reverse opinions are very sharp, indeed. Nature editor John Maddox says that, "When it comes to promoting somebody, it's almost as bad to be presented with a list of citations to his various papers, as to be presented with the weight of those same papers in grams" (Taubes, 1993). R.C. Von Borstel, a geneticist at the University of Alberta says that citation analysis is a bean counter approach. (Taubes, 1993)

In measuring publication performance, complexity arises around the incapability of number of publications in showing the quality of the work. Hamilton (1990) indicates that 10% of the journals get 90% of the citations. If citations are really an indicator of quality and a way of communication of scientific works, then it can be concluded that, 90 percent of academic work is produced just to be wasted because of not contributing to scientific knowledge.

Allan Bard, editor of the Journal of the American Chemical Society complains that, she finds 60 papers in her mailbox when she is in tenure committee, and it is obvious that she is not going to read them all. She says that, "publication is no longer represents a way of communicating with your scientific peers, but a way to enhance your status and accumulate points for promotion and grants" (Hamilton 1990).

Peer review is a more detailed analysis. However, it is not possible for high aggregation level and it is subjective. Barker (2007) states that peer review is not enough itself because there is a lot of uncertainty about consistency and comparability of the peer judgments which make up the results.

The problem in 'measuring science' phenomena is not only its complexity, but also the possible negative results in scientists' research practices. The concern is 'measuring science' may affect science negatively.

In literature, we see many examples of changing research practices of scientists towards changing performance measurement criteria. Moed (2008) shows that, in UK, when researchers are asked to publish in high numbers, they simply increase their number of yearly publications. When they are asked only quality of their publications, then they start publishing in journals, which have high journal impact factor. Dictating high number of citations considering citations a quality measure, makes institutions stimulate researchers to collaborate or at least to co-author. Similarly, Butler (2004) presents the case in Australia as when the "publications" item is added to the funding formula without adding any weight for quality of the publication or quality of the journal that the publication is published in, there happens an obvious increase in number of publications but increase concentrates in lower ranked journals where it is easier to place additional articles.

Regarding the citation element in the performance measure formula, Columbia University sociologist of science Jonathan Cole says that "people may have a tendency to abuse the citations, reify their meaning, put too much authority in the individual numbers as associated with individual scientists" Taubes (1993).

James Duderstadt, president of University of Michigan criticizes the academic promotion system. He says that the growing number of journals and the high number of uncited articles simply confirm the suspicion that academic culture encourages spurious publication. Frank Press, president of the National Academy of Sciences notes that most of the papers are me-too type of follow-on papers or the journals are printing too much. (Hamilton, 1990)

Chairman of the astronomy department at Columbia University says that, "the obvious interpretation that the publish or perish syndrome is still operating in force" (Hamilton, 1990).

2. PROBLEM DESCRIPTION AND RESEARCH OBJECTIVES

The studies and concerns summarized show the importance of a comprehensive analysis of the problem. This study models the dynamics of above-mentioned citation-publication issues. Leaving the complexity of measuring science issue behind, we will focus on the question of what performance measures may improve the research performance and what measures may harm it.

It is assumed that there is citation pressure on researchers rising from concerns regarding quality. There is also publication pressure on researchers rising from concerns regarding publication productivity performance. The source of concerns may be one of or a combination of self-satisfaction of researchers, management they are responsible to, some kind of funding formula or decision criteria applied by promotion and tenure committee. The behaviors of faculty members are analyzed under the assumption that publication pressure makes them publish for large numbers and citation pressure makes them head towards journals with high journal impact factor.

Real citation-publication data is used for initialing the model and estimating its parameters. The data belongs to Boğaziçi University Engineering faculty for years 1981-2006.

The aim of the model is twofold. First, we seek to see the long run publication behavior of faculty members under the assumptions we determined. We explored where the faculty will be in terms of citation and publication performance in the future, if she/he goes on making research in a particular manner. Secondly, some policies are developed as different combinations of performance measures. The policies are; upgrading the publication benchmark, concentrating on mostly publication productivity rather than quality, allowing faculty members devote more of their time on research activities, stimulating the faculty members to have more internal citations, stimulating the faculty members to publish for quality while not focusing on quantity. The policy analysis part aims at finding good policies that will take the faculty to better positions by balancing different aspects of publications and citations.

3. LITERATURE REVIEW

Moed (2008) presents a detailed bibliometric analysis of the UK publication output during the time period 1985-2004. He tries to understand the possible effects of Research Assessment Exercise (RAE) upon scientists' publication practices and the effects of funding procedures upon the performance of a national research system. The most recent RAEs had been done in 1992, 1996 and in 2001 when Moed wrote his paper. In the RAE 1992, total publications counts were requested. Prior to that year, UK scientists substantially increased their article production. In the RAE 1996, a shift occurred in evaluation criteria from quantity to quality. The publication data requested was up to 4 'best' publications per research active staff member. UK scientists gradually increased their number of papers in journal with a relatively high citation impact. In RAE 2001 the criteria were emphasizing quality again. During 1997-2000, institutions raised their number of active research staff by stimulating their staff members to collaborate more intensively or at least to co-author more intensively, although their joint paper productivity did not. Moed (2008) concludes that, "along the way towards the RAE 2001, evaluated units in a sense shifted back from 'quality' to 'quantity'".

Barker (2007) points out one weakness of RAE as it is a reward for research-based institutions, since it counts the published research papers. She gives medicine as an example. She says practice is very important in medicine but RAE has created tensions between research, teaching and the practice of medicine in many university medical schools.

Barker (2007) also criticizes the peer review in RAE. She says that peer Review causes "grade inflation, reinforcement of existing hierarchies, underrating of areas which are not strongly disciplinary or theoretical". She adds that there is lot of uncertainty about consistency and comparability of the peer judgments which make up the results. However, she admits that substituting direct peer review with metrics would remove many of these problems but bring other ones (Barker, 2007).

Butler (2004) used bibliometric data to examine the effects of the policy change in Australian universities on academic output. She found that Australian university publication output increased significantly in response to the "publications" item in the funding formula. She adds that, as there is no attempt to weight for the quality of either the output itself, or the publication in which it appears, increase in journal output is concentrated in lower ranked journals, where it is easier to place additional articles. Figure 3.1 is taken from Butler's paper. She distributed the journals into quartiles according to the journal impacts. For example, Quartile 1 includes the journals with highest impact factors, and Quartile 4 includes the journals with the lowest impact factors. On the vertical axis, we see the percent share of Australian universities' papers in those journals. We see a sharp turning point at year 1993, when number of publications is linked to funding. In the figure that point is shown with the note "introduction of publications collection". She also makes us realize that the share of publications in journals with lower impact factor increases more than in the journals with higher impact factor. She adds that, for smaller institutions, this "number of publications" item is more rewarding and easier to improve than the others (Butler 2002).

Butler (2004) also studied big research sites of Australia other than the universities which are; the Commonwealth Scientific and Industrial Research Organization (CSIRO), the hospitals and the government research agencies. These research sites are not subject to funding formulas like the universities are. She found that, there is no new trend in the publication shares of those research sites. This also supports her conclusions about Figure 3.1.

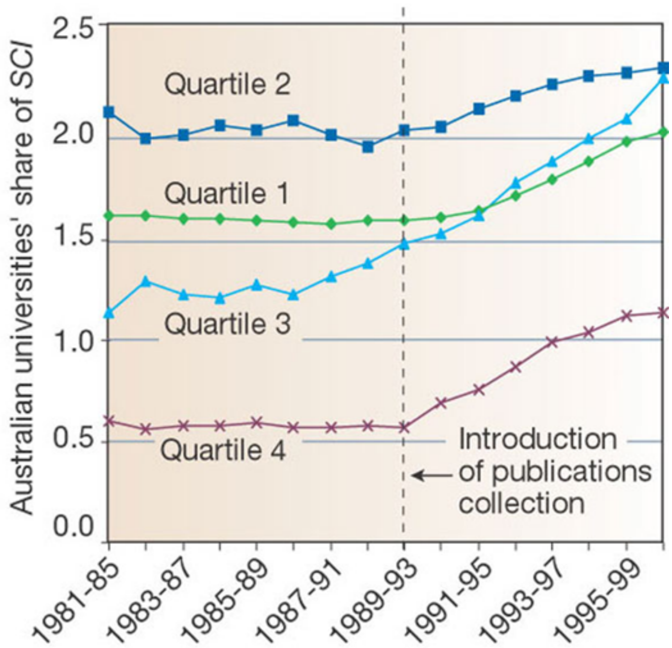

Figure 3.1. Australian universities' share of publication in the SCI, by journal impact quartile: five year window (Butler, 2002)

Besancenot (2006) constructed a good model which examines the quality change in research in response to the incentives. He considered the publication issues in a publication market with supply-demand terms. The supply of papers is the outcome of a simple game between researchers and deans. Researchers must decide on the optimal publication strategy, where deans set up a publication incentive policy so as to stimulate submissions with major journals. The demand is the paper selection process by editors and referees. The model shows that when there is no incentive, top-tier journals publish only high quality papers worked out by top scholars, while normal journals publish good but lower quality papers drafted by normal scholars. When the bonus exceeds a given threshold, at least some normal scholars may choose to submit their work to major journals. Because more normal researchers manage to publish with major journals, the quality of these journals slides down. Moreover, as more submissions arrive into the hands of the editor, he is obliged to call on less accurate referees. As a consequence, chances of top researchers to have their work published decline, a phenomenon which further alters the journal's quality. At the end of the day, the compensation of the best researchers goes down and the research performance, as estimated by the number of papers published in top-tier journals, may fall for the best research institutions.

Hamilton (1990) gives some remarkable statistics. He indicates that 10% of the journals get 90% of the citations. James Duderstadt, president of University of Michigan criticizes the academic promotion system. He says that the growing number of journals and the high number of uncited articles simply confirm the suspicion that academic culture encourages spurious publication. Frank Press, president of the National Academy of Sciences notes that most of the papers are me-too type of follow-on papers or the journals are printing too much.

Allan Bard, editor of the Journal of the American Chemical Society complains that, she finds 60 papers in her mail box when she is in tenure committee, and it is obvious that she is not going to read them all. She says that, "publication is no longer represents a way of communicating with your scientific peers, but a way to enhance your status and accumulate points for promotion and grants". (Hamilton 1990)

Chairman of the astronomy department at Columbia University says that, "the obvious interpretation that the publish or perish syndrome is still operating in force". (Hamilton 1990)

Number of citations as a performance measure has been debated a lot. Taubes (1993) briefly gives the opinions of scientists. For example Columbia University sociologist of science Jonathan Cole says that "people may have a tendency to abuse the citations, reify their meaning, put too much authority in the individual numbers as associated with individual scientists". Some scientists tell that citations does not tell the full story, especially when the analysis gets down to the level of individual scientists. R.C. Von Borstel, a geneticist at the University of Alberta says that citation analysis is a bean counter approach. Nature editor John Maddox adds, "When it comes to promoting somebody, it's almost as bad to be presented with a list of citations to his various papers, as to be presented with the weight of those same papers in grams". (Taubes, 1993) There are some technical complaints on the issue like self citation, negative citation, the type of the publication and the size of the units being evaluated. Taubes (1993) presents those technical issues briefly. Moed (2005, s. 80) says that "Scientists have many tasks and duties. Citation analysis does not take into account all of them. Citation analysis assesses the contribution at the international research front". Moed (2005, s.202) points out that citation analysis is a very good measure of the quality of scientific work to be used in sociological studies of science. But, he adds that it is not perfect and not for individual decisions. (Moed, 2005, s. 202) He also argues that what citation analysis measures is authoritativeness of a paper, its rhetorical strength. (Moed, 2005, s. 203)

Journal impact factor is another performance indicator. Besancenot (2006) says that a few of the journals can be considered as "major" or "top-tier" given their world wide notoriety and ability to shape future research. Reedijk (2008) mentions the possible tricks that can make journal impact factor unreliable. One of the concerns of Reedijk is that editors or even referees stimulate authors to cite their journal. He adds that, since the calculation of the journal impact factor is based on a two absolute years, i.e. the time period covers two years starting from beginning of the first year and ending at the end of the second, the journals publish the "expected top-cited" papers early in the year. He says that the journals may accept the fashionable topics. He concludes that impact factor can easily be manipulated by editorial strategies and policy makers should be aware of that.

In literature, there are some cautions and suggestions concerning how to use those performance indicators. Some of them are presented below very briefly. Coccia(2008) refers to a previous study which compared five measures of performance in UK universities during 1980s. The finding is that no university performed either consistently well or consistently badly across all indicators (Coccia, 2008). So, a good performance measure should never rely on one basic indicator.

Combining peer-review with bibliometric indicators is a very frequently suggested policy. Coccia (2008) says that to reduce the risk of wrong research evaluation, the mathematical techniques have to be associated with other qualitative approaches such as peer review. Maddox says that anyone on a tenure committee should have the time and sense to read and understand the applicants' papers and judge for himself, rather than relying on citation impact data (Taubes, 1993).

Some universities have begun limiting the number of papers they will accept for evaluation. For example, the promotion committee of The Harvard Medical School only reviews applicants' 5 to 10 most significant papers. (Hamilton, 1990) The purpose of this application is to give the promotion committee more time to evaluate each paper.

Aggregation is another issue that should be taken into account according to the findings in literature. Moed, who has studied a lot on the bibliometric analysis issue, says that "bibliometric analysis may be highly useful to policy decision makers when they are applied at higher levels of aggregation aiming at providing insight in more general characteristics of scholarly activity". (Moed, 2005, s. 33) As the most appropriate level of aggregation in citation analysis, Moed (2005, s.87) suggests "research group" rather than a single individual. He adds that "a methodology, even if it provides invalid outcomes in individual cases, may be beneficial to the scholarly system as a whole" (Moed, 2005, s. 34). Suzan Cozzens says that, "the smaller the unit you're trying to evaluate with citation data, the more sensitive it has to be, and the more dangerous it can be. (Taubes, 1993)

Making the measurements for different fields separately is also a widely accepted strategy. In a study about RAE, Barker (2007) says that "it would be appropriate to compile and publish rankings of universities per research field or discipline".

Moed suggests some tips to follow to make the use of bibliometric indicators more appropriate. He suggests that a bibliometric indicator should be "formal, open, scholarly founded, supplemented with expert and background knowledge, carried out in a clear policy context, stimulating users to explicitly state basic notions of scholarly quantity, enlightening rather than formulaic". (Moed, 2005, s. 28)

4. METHODOLOGY

System Dynamics methodology is employed in modeling the dynamics of academic citation-publication problem. Barlas (2002) explains the system dynamics discipline with the words:

> System dynamics discipline deals with dynamic policy problems of systemic, feedback nature. Such problems arise from the interactions between system variables and from the feedbacks between the managerial actions and the system's reactions. The purpose of a system dynamics study is to understand the causes of a dynamic problem, and then search for policies that alleviate/eliminate them.

The problem in hand is appropriate to be modeled with system dynamics modeling due to typical properties necessitating systems approach.

There are circular causal relations between the variables which can be shown by feedback loops. The 'causal effect diagram' showing the circular causal relations between the variables can be seen in Figure 5.1. The problem is dynamic. Variables change over time as they interact. The changes are not straightforward to predict. There are time delays involved between causes and effects and between actions and reactions. The main cause of dynamic behavior is the internal structure of the system. This systemic/endogenous perspective is defined by Barlas (2002) as 'the structure causes the behavior of the system'. Since the dynamics are formed by internal structure but not purely external forces, managerial control and improvement is possible, which is the main purpose of the study.

The methodology consists of the following major steps:

- Problem description and studying objectives
- Conceptual model and data analysis
- Construction of the formal model
- Model testing and validation
- Scenario and policy experiments

- Policy recommendations and conclusions
- Implementation

5. OVERVIEW OF THE MODEL

The dynamic simulation model consists of the faculty members of a school, their publications and the citations those publications receive. The purpose of the study is to examine the behaviors of researchers in response to the dynamics of various publication and citation pressures.

The model is composed of 6 sectors. The sectors correspond to research time, publication, publication and citation pressures, skill, reputation and citation.

In the following sections, general overviews of the sectors are presented. Underlying assumptions, the approach used, data used in the initialization, structural details, equations and the dynamics of sectors will be discussed throughout the next chapter.

5.1. Research Time Sector:

Faculty members have various kinds of jobs to do. These jobs can be administrative, attending lectures and making research. In this model we are dealing with the research activities of the faculty. The *Research Time* shown in the first loop represents average time of the faculty members that is devoted to research activities. It is assumed that those research activities end up with writing academic papers and submitting them to academic journals. *Research Time* is not constant. It increases or decreases depending on the publication pressure felt by the faculty members.

5.2. Publication Sector

In the model, the faculty members write three kinds of papers. Those papers are called as A, B and C type; namely high quality, medium quality and low quality papers. It takes very long time to write a high quality paper. In return that paper is published in a high quality journal. On the other hand if you write a medium quality paper,which requires a shorter time to be written, that paper is published in a medium quality journal. Similarly, a low quality paper which can be written very fast, is published in a low quality journal. The journals are classified into quality categories according the average number of citations received by the publications in the journals. In the model, the journals are classified into 3 quality categories. A paper published in a high quality, namely *A type journal*, receives more citations per year than a paper which is published in medium quality, namely *B type journal.* Similarly a paper published in a *B type journal*, receives more citations per year than a paper which is published in low quality, namely *C type journal.* Approximately in the first two years after being published, the publications are called newborn publications and are assumed to get no citations. After about 2 years, the publications are active publications and they get citations until they die. The life of the active publications are about 20 years. *A type publications* become living publications faster than *B type publications* and *B type publications* become active publications faster than *C type publications.* On the other hand, *A type publications* live longer than *B type publications* and *B type publications* live longer than *C type publications.* After they die, the publications get no more citations and they are called obsolete publications.

5.3. Publication and Citation Pressures Sector

There is an assumption that, research performance is quantifiable and the faculty uses two main research performance measures. The first one is "average number of publications per faculty per year". The second one is "average citations received per publication". These two performance measures of the faculty are compared with reliable benchmarks. World data is chosen to be the benchmark. The average number of publications per faculty per year in engineering fields in recent years in the world is calculated to be compared with the publication performance of the faculty. The average number of citations received by the publications in engineering fields in the world is calculated to be compared with the citation performance of the faculty. For the future years, the world's performance measures are estimated using the previous years' data. If the *average number of publications per faculty per year* is less than the world average, faculty members feel a publication pressure. On the other hand, if the *average number of citations per paper* is less than the world average, faculty members feel a citation pressure. The higher the gap between faculty's and the world's performance measures, the stronger the pressure felt by faculty members.

An assumption is that, it is in the faculty's hands to make decisions about how to distribute their research time between research activities. The main dynamics of the model comes on stage with this decision. Under the publication and citation pressures, faculty members decide on writing *A, B or C type papers.* It is assumed that, if there is publication pressure on the faculty, they tend to ignore quality and try to write as many papers as they can. This pressure pushes them to write *C type papers* because *C type papers* are easy to write and they are written in a short time. They tend to use their research time more in writing *C type papers* and less in writing *A type papers.* On the other hand, if there is citation pressure, quality will be indispensable because, only high quality publications receive high numbers of citations. Citation pressure will push the faculty members to write *A type papers* which are not easy to write, require a long time but get higher number of citations. In the absence of any type of pressure, *B type paper*s are written. If both of the pressures are felt at the same time, faculty members try to make both *A* and *C type papers* to deal with both of the pressures.

5.4. Skill Sector

Skill level of faculty is a combination of many qualities of the faculty. Experience, financial support, accessibility to research materials are some of these qualities. In order to keep the model simple, this variable is included in the model as an exogenous variable. *Skill* level has a positive effect on *publish rate.* It can be said that thanks to having a high level of *skill,* the required time for writing a paper is shorter, so it is possible to write more papers in less time. *Skill* level has a positive effect on the number of citations received as well.

5.5. Reputation Sector

Having reputation in academic world means to be known for making good research. This good esteem makes your publications read by other researchers. Other researchers who read your publications give citations to your publications. The more citations your publications receive, the more visible you are in the academic world. Therefore, *average number of citations per publication* and *reputation* have direct effects on each other.

The papers submitted to journals are either accepted or rejected by the journals. In the model, a particular fraction of the submitted papers are accepted by the journals. Acceptance fraction changes depending on the reputation of the faculty. *A type papers* are submitted to *A type journals*, *B type papers* are submitted to *B type journals* and *C type papers* are submitted to *C type journals.* This makes it possible to assume that acceptance fraction is roughly the same for all of the three paper types.

5.6. Citation Sector

The citations received by the publications accumulate in two kinds of stocks in the model; *External Citations* and *Internal Citations. External citations* are received by papers which are not written by faculty members. Reputation has a strong effect in this kind of citation. On the other hand, *Internal Citations* are given by known colleagues or the authors of the papers themselves. For this kind of citations, reputation is not necessary because the colleagues already know each other well. *Skill* level of the faculty has a positive effect on both citation types. Although each type of paper is submitted to the related type of journal, like *A type paper* to *A type journal*, it cannot be said that all the *A type papers* in an *A type journal* receive the same number of citations. *Skill* level provides this difference in citation receiving rates between two *A type papers* in an *A type journal.*

Figure 5.1 provides a brief causal-loop diagram of the overall model.

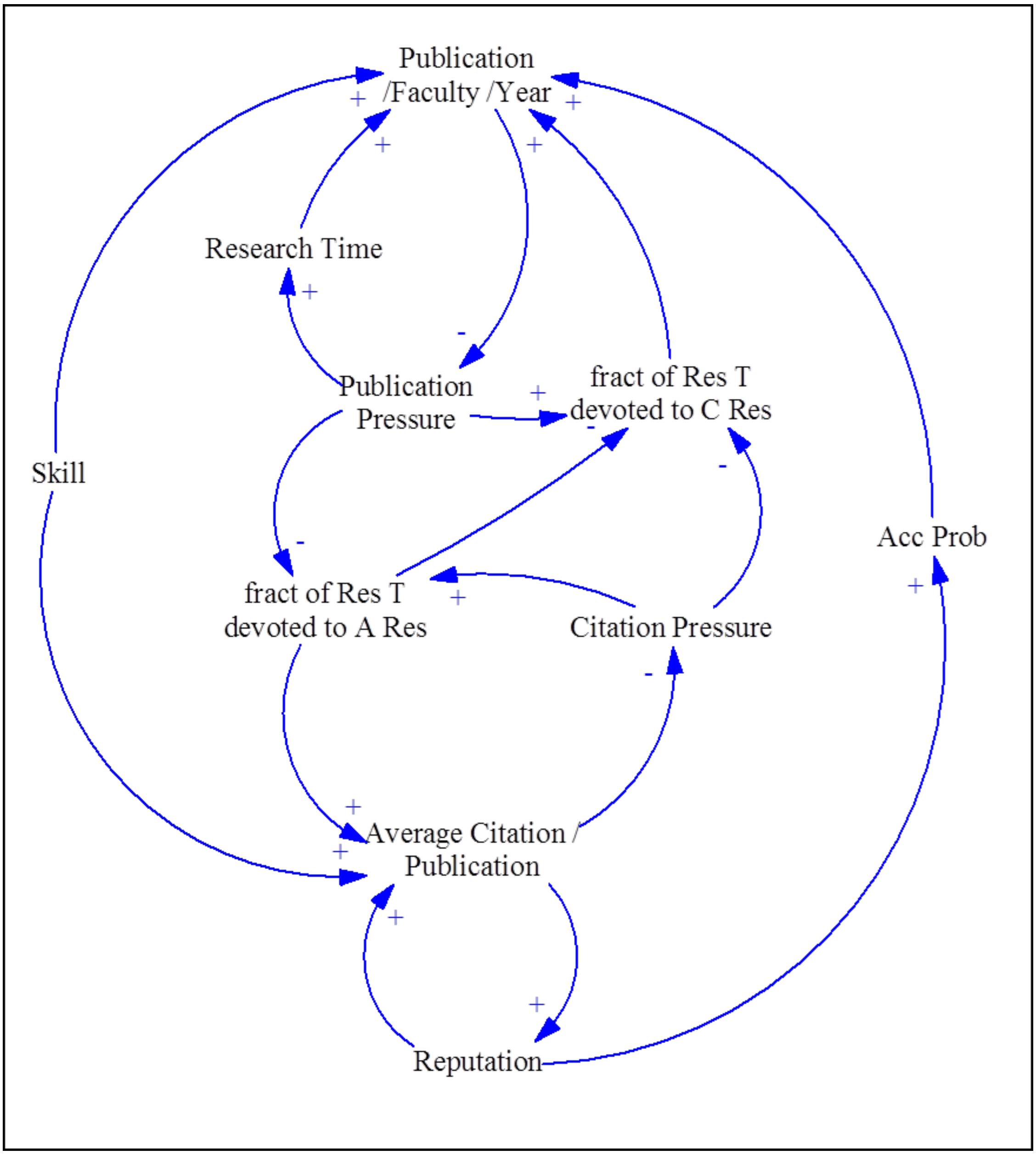

Figure 5.1. Causal-loop diagram of the overall model.

The model simulates the publication and citation dynamics of Engineering Faculty of Boğaziçi University between years 1995 and 2040. The model is initialized with real data from Boğaziçi University. Time unit is a year.

All model variables with their definitions, types and dimensions are provided in Table 5.1.

Table 5.1. All model variables and parameters with their definitions, types and dimensions

Variable	Definition	Type	Dimension
Paper Submitted A	Paper Submitted A	Stock	Paper
Paper Submitted B	Paper Submitted B	Stock	Paper
Paper Submitted C	Paper Submitted C	Stock	Paper
Newborn Pub A	Newborn Publication A	Stock	Paper
Newborn Pub B	Newborn Publication B	Stock	Paper
Newborn Pub C	Newborn Publication C	Stock	Paper
Publication A	Publication A	Stock	Paper
Publication B	Publication B	Stock	Paper
Publication C	Publication C	Stock	Paper
Obsolete Pub	Obsolete Publication	Stock	Paper
External Citation	External Citation	Stock	Citation
Internal Citation	Internal Citation	Stock	Citation
Perceived Reputation	Perceived Reputation	Stock	unitless
Desired fA	Desired fraction for A	Stock	unitless
Desired fC	Desired fraction for C	Stock	unitless
fract of Res T for A	Fraction of Research Time for A Research	Stock	unitless
fract of Res T for B	Fraction of Research Time for B Research	Stock	unitless
fract of Res T for C	Fraction of Research Time for C Research	Stock	unitless
Tot Pub in 3yr	Total Publications in 3 years	Stock	Paper
Research Time	Research Time	Stock	Year / Faculty / Year
Paper Writing Rate A	Paper Writing Rate A	Flow	Paper / Year
Paper Writing Rate A	Paper Writing Rate A	Flow	Paper / Year
Paper Writing Rate A	Paper Writing Rate A	Flow	Paper / Year
Publish R A	Publish Rate A	Flow	Paper / Year
Publish R B	Publish Rate B	Flow	Paper / Year
Publish R C	Publish Rate C	Flow	Paper / Year
Reject R A	Reject Rate A	Flow	Paper / Year

Table 5.1: All model variables and parameters with their definitions, types and dimensions (Continued)

Variable	Definition	Type	Dimension
Reject R B	Reject Rate B	Flow	Paper / Year
Reject R C	Reject Rate C	Flow	Paper / Year
Mature R A	Mature Rate A	Flow	Paper / Year
Mature R B	Mature Rate B	Flow	Paper / Year
Mature R C	Mature Rate C	Flow	Paper / Year
Obsolete R A	Obsolete Rate A	Flow	Paper / Year
Obsolete R B	Obsolete Rate B	Flow	Paper / Year
Obsolete R C	Obsolete Rate C	Flow	Paper / Year
Ext C R	External Citation Receiving Rate	Flow	Citation / Year
Int C R	Internal Citation Receiving Rate	Flow	Citation / Year
Per Rep Change	Perceived Reputation Change	Flow	1 / Year
change in fA	Change in fraction of high	Flow	1 / Year
change in fC	Change in fraction of low	Flow	1 / Year
transition A B	Transition between A and B	Flow	1 / Year
transition B C	Transition between B and C	Flow	1 / Year
Tot Pub R	Total Publish Rate	Flow	Paper / Year
Trash	Trash	Flow	Paper / Year
Res T adj rate	Research Time Adjustment Rate	Flow	1 /Faculty/ Year
Faculty	Faculty	Auxiliary	Faculty
Initial Faculty	Faculty	Auxiliary	Faculty
Faculty Increase Rate	Faculty Increase Rate	Auxiliary	Faculty / Year
required T A	Required Time A	Auxiliary	Year / Paper
required T B	Required Time B	Auxiliary	Year / Paper
required T C	Required Time C	Auxiliary	Year / Paper
Publish T	Publish Time	Auxiliary	Year

Table 5.1: All model variables and parameters with their definitions, types and dimensions (Continued)

Variable	**Definition**	**Type**	**Dimension**
Reject Time	Reject Time	Auxiliary	Year
Mature T A	Mature Time A	Auxiliary	Year
Mature T B	Mature Time B	Auxiliary	Year
Mature T C	Mature Time C	Auxiliary	Year
Obsolete T A	Obsolete Time A	Auxiliary	Year
Obsolete T B	Obsolete Time B	Auxiliary	Year
Obsolete T C	Obsolete Time C	Auxiliary	Year
Ext Cit /P/Y A	External Citation per Publication per Year A	Auxiliary	Citation / Paper / Year
Ext Cit /P/Y B	External Citation per Publication per Year B	Auxiliary	Citation / Paper / Year
Ext Cit /P/Y C	External Citation per Publication per Year C	Auxiliary	Citation / Paper / Year
Int Cit /P/Y A	Internal Citation per Publication per Year A	Auxiliary	Citation / Paper / Year
Int Cit /P/Y B	Internal Citation per Publication per Year B	Auxiliary	Citation / Paper / Year
Int Cit /P/Y C	Internal Citation per Publication per Year C	Auxiliary	Citation / Paper / Year
Avg Pub/F/y	Average Publication per Faculty per Year	Auxiliary	Paper / Faculty / Year
W avg Pub/F/y	World Average Publication per Faculty per Year	Auxiliary	Paper / Faculty / Year
Skill	Skill	Auxiliary	unitless
Acc Percentage	Acceptance Percentage	Auxiliary	unitless
Acc Fraction	Acceptance Fraction	Auxiliary	1/Year
Reject Portion	Reject Portion	Auxiliary	unitless
Act Rep	Actual Reputation	Auxiliary	unitless
Rep AT	Reputation Adjustment Time	Auxiliary	Year
W avg Ext Cit	World Average External Citation	Auxiliary	Citation / Paper
W avg Int Cit	World Average Internal Citation	Auxiliary	Citation / Paper
AvgExtC/P	Average External Citation per Paper	Auxiliary	Citation / Paper

Table 5.1: All model variables and parameters with their definitions, types and dimensions (Continued)

Variable	Definition	Type	Dimension
AvgIntC/P	Average Internal Citation per Paper	Auxiliary	Citation / Paper
W Avg Cit per Pub	World Average Citation per Publication	Auxiliary	Citation / Paper
Normal fA	Normal fraction for A	Auxiliary	unitless
Normal fC	Normal fraction for C	Auxiliary	unitless
fA goal	Fraction for A goal	Auxiliary	unitless
fC goal	Fraction for C goal	Auxiliary	unitless
fA AT	Fraction for A Adjustment time	Auxiliary	Year
fC AT	Fraction for C Adjustment time	Auxiliary	Year
AB AT	A B adjustment time	Auxiliary	Year
BC AT	B C adjustment time	Auxiliary	Year
Eff of Rep on Acc Perc	Effect of Reputation on Acceptance Percentage	Auxiliary	unitless
Eff of Skill on Pub	Effect of Skill on Publications	Auxiliary	unitless
Eff of Skill on Cit	Effect of Skill on Citations	Auxiliary	unitless
Eff of Pub Press on Res T	Effect of Publication Pressure on Research Time	Auxiliary	unitless
Eff of Rep on Ext Cit	Effect of Reputation External Citation	Auxiliary	unitless
Eff Ext Cit on Rep	Effect of External Citation on Reputation	Auxiliary	unitless
Eff Int Cit on Rep	Effect of Internal Citation on Reputation	Auxiliary	unitless
Eff Cit Pr on fract A	Effect of Citation Pressure on fraction for A	Auxiliary	unitless
Eff Cit Pr on fract C	Effect of Citation Pressure on fraction for C	Auxiliary	unitless
Eff Pub Pr on fA	Effect of Publication Pressure on fraction for A	Auxiliary	unitless
Eff Pub Pr on fC	Effect of Publication Pressure on fraction for C	Auxiliary	unitless

6. DESCRIPTION OF THE MODEL

In this chapter all the model variables and parameters are explained in detail. The stock-flow structure of the whole model is provided in Figure C.1, C.2 and C.3.

6.1. Publication Sector

6.1.1. Background Information

Papers “live” in different conditions throughout their lifetimes. They are born, get mature, receive citations, and then they die. But, every paper will not have the same life. Some of them are good quality ones. They attract more attention and receive citations more than the others. Those good quality papers mature fast and live longer than the others. There are even some top quality papers which never die. Those are the core papers of a field.

In the model, the papers start their lives and complete their journey through different routes composed of stocks according to their quality class.

For modeling the aging structure of the papers, the findings of Lariviere (2008) are adopted.

The papers and journals are categorized according to quality. The quality classification depends on the average number of citations received by the publications in the journals. This categorization is consistent with ‘Journal Impact Factor’ which is a measure of journal quality. The Journal Impact Factor was developed by Eugene Garfield (Garfield, 1972). The impact factor of a particular journal in a particular year is defined as: the number of citations received in that year by all documents published in that journal in the last two years, divided by the number of citable documents published in that journal in the last two years (Moed, 2005, p.92).

Journal impact factor is exposed to many criticisms because of its weaknesses. The most basic criticism is that it only measures the citation impact of articles in the second and third year after publication. It is therefore biased towards journals revealing a rapid maturing or decline in citation impact (Moed, 2005, p.40). However, journal impact factor is now in use as a quality indicator. In addition, our model considers not only the second-third year citations but all of the citations received by papers throughout their lives.

6.1.2. Assumptions

When a paper is submitted to a journal, it is subjected to peer review. Some of the papers are rejected by the journal. This model does not deal with the rejected papers. Rejected papers are either discarded or revised by the researcher. The revised papers are assumed to enter the system again as a new paper through the paper writing rate flow.

In classifying the papers according to quality, the citations of the papers are taken into consideration. The study is done with the citations received in the first 8 years of the publications. This approach is based on the foundation of Lariviere (2007). According to their findings, approximately 62 per cent of the citations are received in the first 10 years of a publication.

6.1.3. Description of the Structure

Papers act differently throughout their lifetimes. After being written, papers stay in four stocks for varying times. The four stocks are called; *Paper Submitted*, *Newborn Publication*, *Publication*, *Obsolete Publication*. The details of the stocks are explained throughout this section. Basic stock flow structure is seen in the Figure 6.1.

<u>6.1.3.1. Paper Submitted Stock.</u> The first of four publication stocks is *Paper Submitted* stock. After a paper is written by researchers, that paper is submitted to a journal

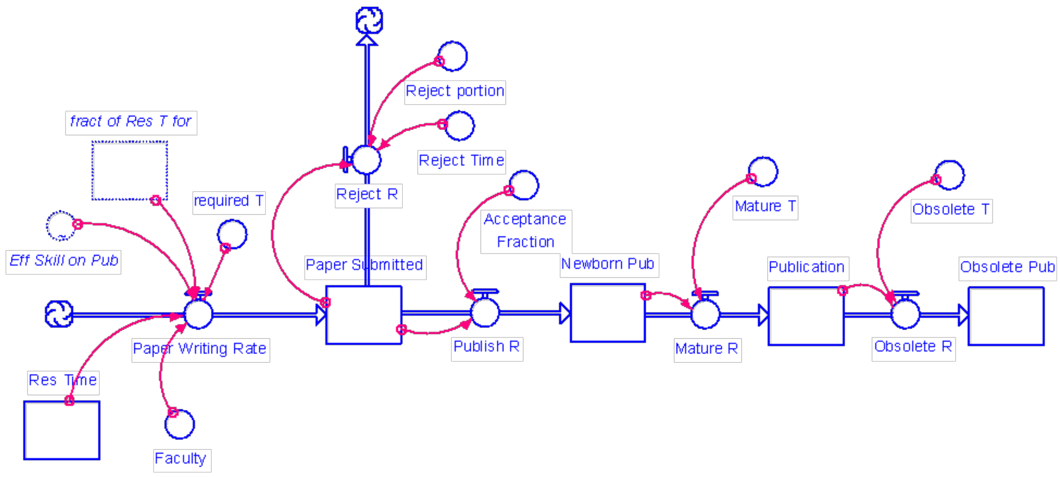

Figure 6.1. Basic Stock Flow Structure of Publication Stocks

to be published. The peers read the paper and decide on whether accepting or rejecting the paper. This stock stands for representing the papers that are under peer review.

$$Papersubmitted(t) = Papersubmitted(t - dt) + \\ + (PaperWritingRate – PublishRate – RejectRate) * dt \quad (6.1)$$

The inflow of this stock is *Paper Writing Rate*. The equation of the inflow is:

$$PaperWritingRate = NumberofFaculty * EffSkillonPub * \\ * ResearchTime * \frac{fractofResTforA}{requiredtime} \quad (6.2)$$

Number of Faculty is the real number of Bogaziçi University Engineering faculty members. The numeric values are presented in the Section 6.1.4. *Eff Skill on Pub* is a positive effect. It is assumed that, the more skilled the faculty members, the higher the *Paper Writing Rate6.2.*

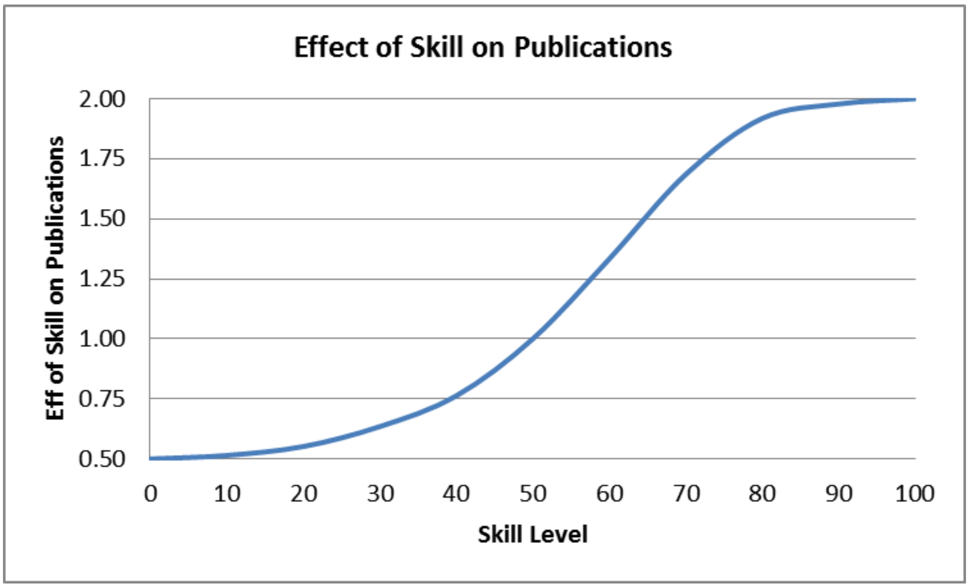

Figure 6.2. Effect of Skill on Publications

Research Time is the fraction of time of the faculty that is devoted to research activities. The parameter *required time* is the required time to write a single paper. The outflows of the stock are *Publish Rate* and *Reject Rate.*

$$AcceptanceFraction = AcceptancePercentage/PublishTime \tag{6.3}$$

$$PublishRate = PaperSubmitted * AcceptanceFraction \tag{6.4}$$

Publish Time is estimated from real data. *Acceptance Fraction* is the fraction of papers in paper submitted stock that are accepted by the journals yearly, according to the peer review. *Reject Time* equals to *Publish Time.*

$$RejectPortion = 1 - AcceptancePercentage \tag{6.5}$$

$$RejectRate = Papersubmitted * \frac{RejectPortion}{RejectTime} \tag{6.6}$$

Values of all parameters will be later given in Section 6.1.4.

6.1.3.2. Newborn Publications Stock. After being published, the publication does not receive very much citation in the first years (approximately one and a half year). In these years, the publications are called *Newborn Publications*. For being a citable publication, the publication needs to be mature. *MatureRate* is the outflow of this stock.

$$NewbornPub(t) = NewbornPub(t - dt) + (PubRate–MatureRate) * dt \tag{6.7}$$

$$MatureRate = NewbornPublication/MatureTime \tag{6.8}$$

Mature Time is estimated from real data, as will be described in Section 6.1.4.

6.1.3.3. Publications Stock. The papers in *Publication* stock are citable papers. The papers stay in this stock until they die. Dying means getting too old to receive citation. They are called *Obsolete Publication* in the model. The outflow of this stock is *Obsolete Rate.*

$$Publication(t) = Publication(t - dt) + (MatureRate–ObsoleteRate) * dt \tag{6.9}$$

$$ObsoleteRate = Publication/ObsoleteTime \tag{6.10}$$

Obsolete Time is estimated from real data, as will be described in Section6.1.4.

6.1.3.4. Obsolete Publications Stock. When a publication becomes very old and gets no more citation, that publication is assumed to be died. Such publications are called *Obsolete Publication* in the model.

$$ObsoletePublication(t) = ObsoletePublication(t - dt) + (ObsoleteRate) * dt \quad (6.11)$$

The papers written by the faculty members are grouped under three categories; A, B and C depending on the quality of the papers. Class A papers are high quality, class B papers are medium quality and class C papers are low quality papers. In the model, the journals are classified into 3 quality categories as well. A high quality paper is published in a high quality journal, a medium quality paper is published in a medium quality journal and a low quality paper is published in a low quality journal. The quality classification of the journals depends on the average number of citations received by the publications in the journals. A paper published in a high quality A journal receives more citations per year than a paper which is published in medium quality B journal. Similarly a paper published in a medium quality B journal receives more citations per year than a paper, which is published in a low quality C journal.

The complete stock flow structure of paper stocks is provided in Figure 6.3.

The parameters *required T*, *fract of Res T*, *Mature T* and *Obsolete T* are different for these three kinds of papers, as will be described in Parameter Estimation section.

The required time to write an A type paper is longer than the required time to write a B type paper. Similarly, required time to write a B type paper is longer than required time to write a C type paper.

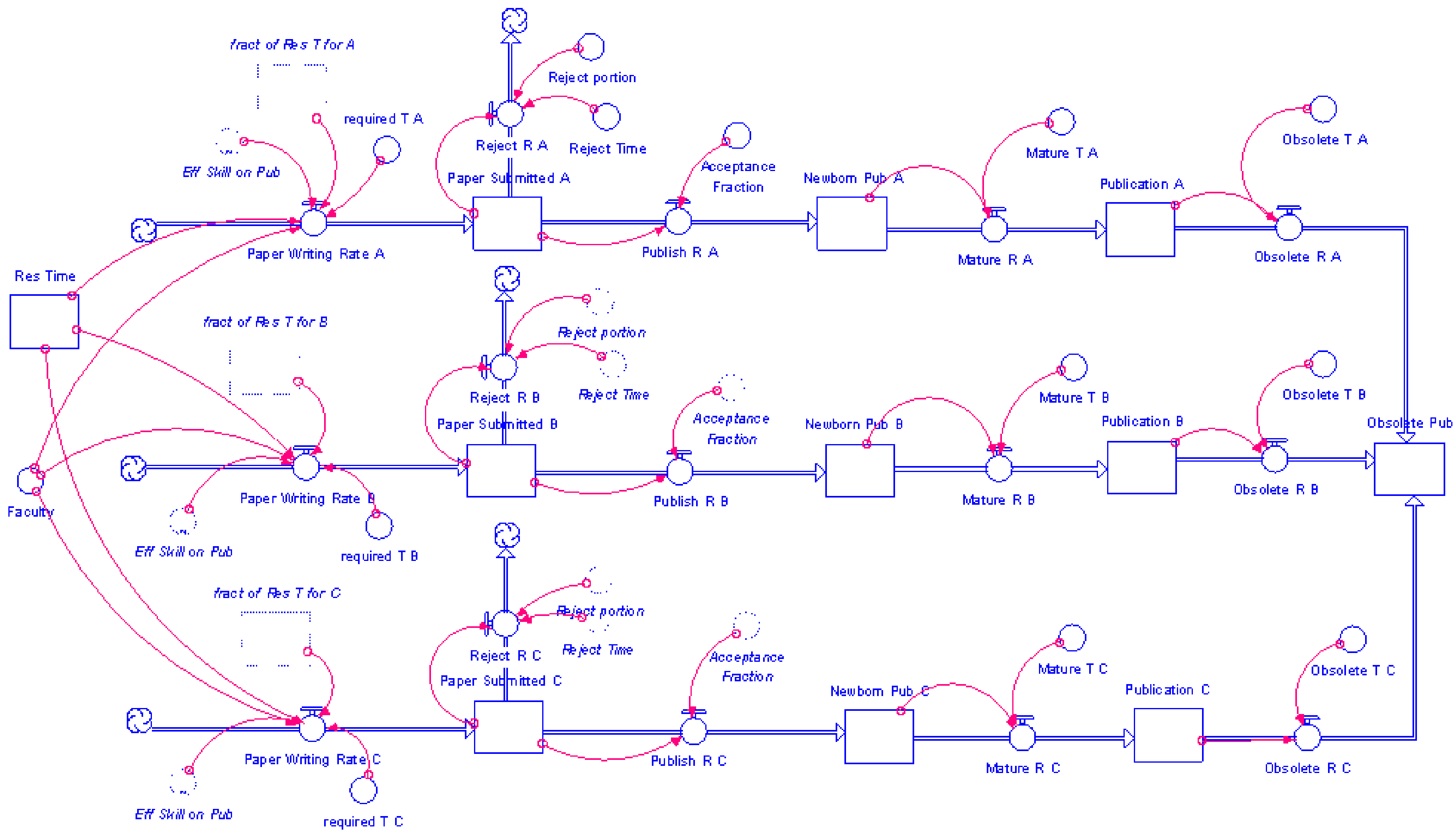

Figure 6.3. Stock-flow structure of publication sector

An assumption is that, it is in the faculty's hands to make decisions about how to distribute their research time between research activities. The main dynamic of the model comes on stage at this decision time. Under the publication and citation pressures, faculty members decide on writing A, B or C type papers. It is assumed that publication pressure pushes the faculty members to write C papers because C papers are easy to write and they are written in a short time. They tend to use their research time more in writing C papers and less in writing A papers. On the other hand, citation pressure pushes the faculty members to write A papers which are not easy to write, require a long time but get high number of citations. In the absence of any pressure, B papers are written. This decision of the faculty members are represented with the *fract of Res T for A/B/C* stocks. In the inflow of *Paper Submitted* stocks, the related *fract of Res T for A/B/C* is included.

A publications live longer than B publications, and B publications live longer than C publications. A publications become mature/citable publications faster than B publications and B publications become mature/citable publications faster than C publications.

6.1.4. Parameter Estimation

All of the stocks are initialized by using real data or estimations based on real data. *required T A/B/C* are estimated according to observations on real life. Initial *Res Time* and *fract of Res T* devoted to A/B/C research parameters are estimated to be consistent with real data. *Publish T*, *Mature T A/B/C*, and *Obsolete T A/B/C* parameters are estimated by using real data in Section6.1.4.4 and in Section 6.1.5.1.

<u>6.1.4.1. World Citations.</u> The average number of citations per publication measure is used in the model as the quality indicator. The benchmark value of this parameter is the average citations per publication value of the world publications.

Data is obtained from Thomson Reuters InCites. InCites is a convenient source that delivers customized, citation-based research evaluation on the web. Data source of InCites is Web of Science (WOS).

Worldwide biomedical engineering, chemical engineering, civil engineering, electrical and electronic engineering, environmental engineering, industrial engineering, manufacturing engineering, and mechanical engineering publications of years 1981-2009 and the total number of citations those publications received up to 2010 are obtained from InCites. The publication type used in the analysis is only “articles”.

The number of publications in each field in each year is shown in FigureA.5. The total number of publications in each year is shown in Figure A.6.

In the simulation model, the average number of citations per publication is compared with the world average of that. This comparison is done continuously. For being able to do that, we need the world average number of citations per publication every year. The InCites data only provides the number of cumulative citations up to year 2010 of those 1981-2009 publications. We used the simplified world publications model to calculate every year’s citations from the cumulative citations data. The MT and OT parameters that are explained in Section 6.1.4.5 are used in the simplified world publications model.

Where World Mature Time equals to 1.8 years and World Obsolete Time equals to 9 years, total number of publications in each year is given to the model separately. World Citations per pub per year parameter is found by trial and error such that it gives the World Citations amount in the life time of the publications in question. For instance, in 1990, 35547 articles were published in the world in the selected engineering fields. Those articles received 402379 citations from 1990 to 2010. In the model, the *World Publish Rate* is given as 35547 with a pulse function which provides a single entry as the publish rate. Time of the simulation is restricted to 20 years since it has been 20 years from 1990 to 2010. The *World cit per pub per year* parameter is fixed at 1,478 so that the number of citations accumulated in World Citation stock is approximately 402379. In the same manner, the *World cit per pub per year* parameter is calculated for every year for the years 1981-2006. This procedure is continued until 2006 because, the publications younger than 2006 publications are too young to show a healthy, measurable citation behavior in receiving citations. The resulting *World cit per pub per year* parameters for years 1981-2006 are provided in Figure A.8.

The values of the parameter *World cit per pub per year* for years 2006-2040 are estimated with a regression analysis. The values of the parameters that are used in the regression shows an increasing behavior every year. However, the slope of the increase has been changed in about year 1995. The regression is based on the values of the parameter after years 1995. The regression analysis is provided in Table A.1. The estimated values are provided in Figure A.9 as well.

Number of Publications published in the world every year after year 2009 is also estimated with a regression analysis. The regression analysis is provided in Table A.2. The estimated values are provided in Figure A.11 as well.

The cumulative number of WOS publications and model publications of the selected engineering fields in the world are shown in Figure A.10. The values obtained from model represent the beginning of year values, but the values obtained from WOS represent the whole year values.

6.1.4.2. Faculty. *Faculty* parameter represents the number of faculty members in Bogaziçi University Engineering faculty.

Number of faculty members between the years 1995-2009 is obtained approximately and shown in the Figure 6.4.

A regression analysis is carried out for estimating the future values and for smoothing the data. Results of regression analysis is provided in Table A.8.

The resulting number of faculty values which is used in the model is shown in the Figure 6.5.

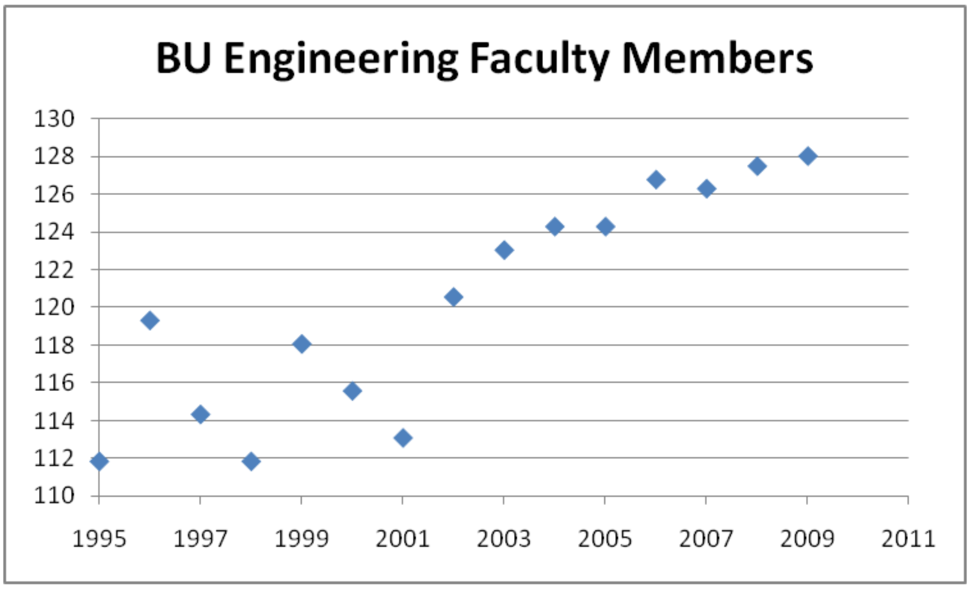

Figure 6.4. Number of BU Engineering Faculty members each year

6.1.4.3. Required time A, Required time B, Required time C. In the model, the *required T* parameters are estimated based on observations from real life. If the total time of a faculty member is taken as 1 year, the required time for writing an A paper is assumed to be 0.8 years, for a B paper it is assumed to be 0.4 years and for a C paper it is assumed to be 0.2 years.

6.1.4.4. Publish Time. *Publish T* is the time between the submission of a paper and its publication in a journal.

71 randomly selected papers of 8 faculty members from engineering faculty of Bogaziçi University are used as the data. The time the papers were submitted, the time the papers were published, and the number of citations those publications receive are obtained.

The average *Publish T* of the 71 papers is 19 months. Chemical engineering is different from the other engineering fields. The average *Publish T* of 16 chemical engineering papers is 9 months. When the chemical engineering papers are excluded, the average *Publish T* in other engineering fields is 22 months.

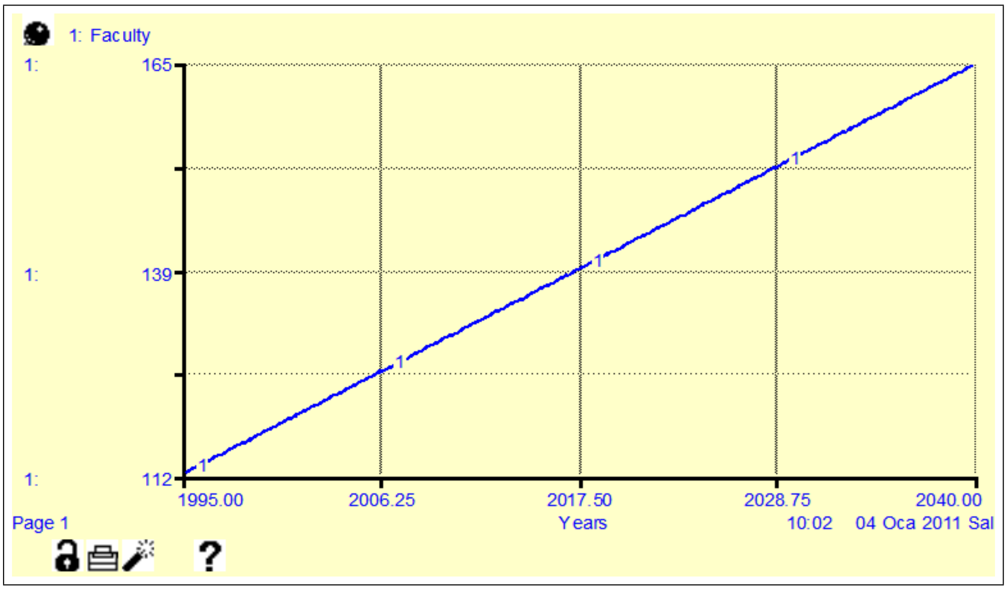

Figure 6.5. Number of the faculty in the model.

To see the effect of time in *Publish T*, the papers are sorted according to their publication years. Figure 6.6 is obtained. *Publish T* of papers shows a similar behavior from year 1996 to 2009. *Publish T* does not change in years.

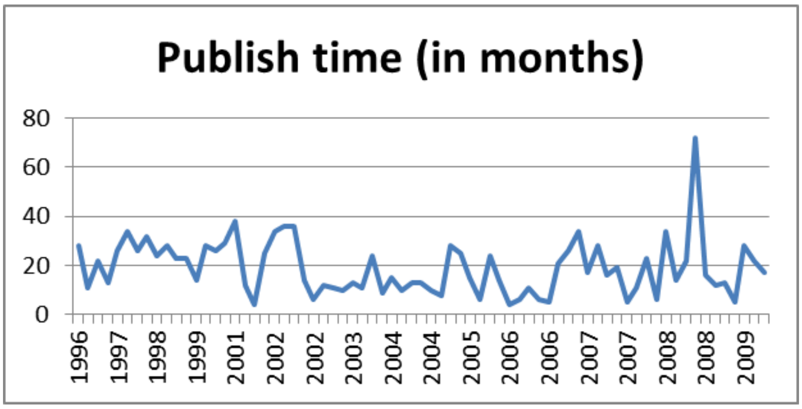

Figure 6.6. Publish time 1996-2009

The papers are sorted according to "average citation per year" values. The aim was to see whether there is a correlation between the quality of the paper and its publish time; considering the per year citation values as a measure of quality. No correlation between quality and publish time is found. Figure 6.7 shows the publish time and average citations per year values of the publications.

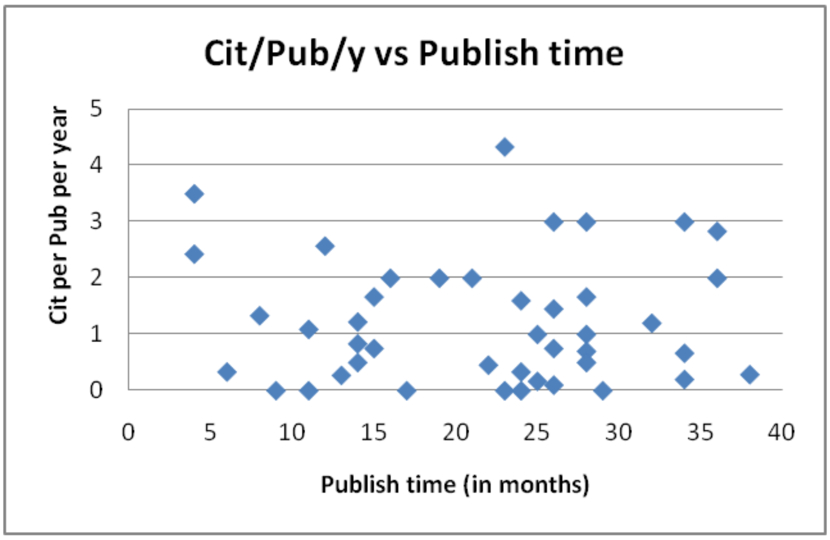

Figure 6.7. Number of citations per publication per year vs publish time

According to the publish time analysis, it can be concluded that the average publish time is not changing with time. It is not depending on quality. The values are listed in the Table 6.1.

Table 6.1. Publish time of chemical engineering compared to other fields

	Publish time in months
Average of all fields	19
Average of chemical engineering	9
Average of fields other than chemical engineering	22

In the model, since we are dealing with the engineering faculty averages in all aspects, the number that is used as the publish time is 19 months = 1.58 years.

6.1.4.5. Obsolete Time & Mature Time for World Data. Lariviere et al. (2008) studied aging and obsolescence of scientific literature. They obtained the data from Thomson Scientific's Century of Science, Web of Science and Science Citation Index for the years 1900-2004. They measured the age and obsolescence of medical and engineering publications. Their findings about engineering fields are employed in this study.

They made their analysis by using the references of papers. In the long run, we assume that behaviors of references given by the papers and citations are similar in terms of age of cited document. With that assumption, we used the data they provide safely for our citation analysis.

They provide the median age of cited literature, average age of cited literature and number of references per article for the world data. In addition they provide the "Price index" which is the percentage of references to material that is 5 years old or younger. This measure was developed by Price (1986) to distinguish fields having fast growth.

Figure 6.8 shows the share of the average number of references per article, by class of age of cited document, for natural sciences and engineering in years 1900-2004.

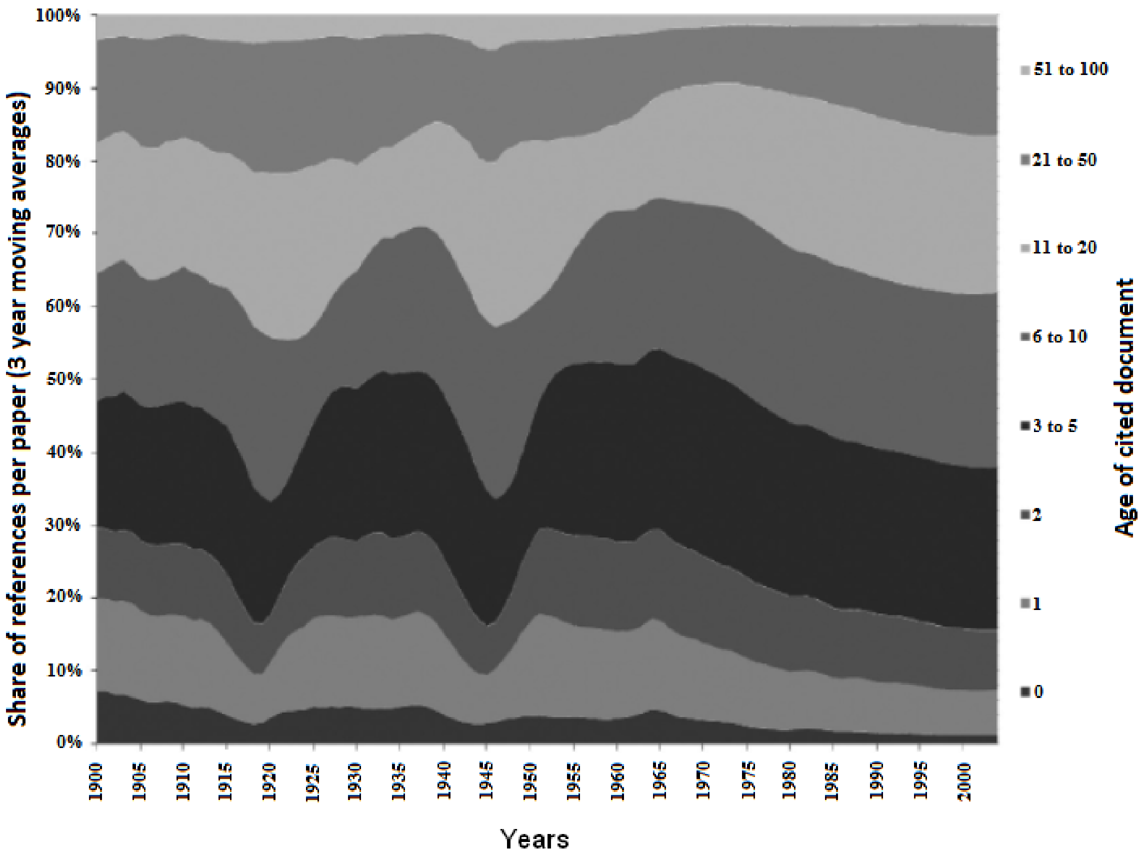

Figure 6.8. Share of the avg # of references per article, by age of cited document, for natural sciences and engineering (Lariviere et al., 2008)

We can obtain the percentage of references with respect to reference's age from Figure 6.8. The percentages are shown in Table 6.2.

Table 6.2. Percentage of references by age

age	percentage of references
0	1,2
1	6,0
2	8,3
3 to 5	22,6
6 to 10	23,8
11 to 20	21,4
21 to 50	15,5
51 to 100	1,2

6.1.5. Publish Time

From Figure 6.8 which shows the age distribution of cited documents, it is possible to draw citation distribution of an average publication according to publication's age. The graph of citation distribution of a publication according to publication's age is drawn in Figure 6.9.

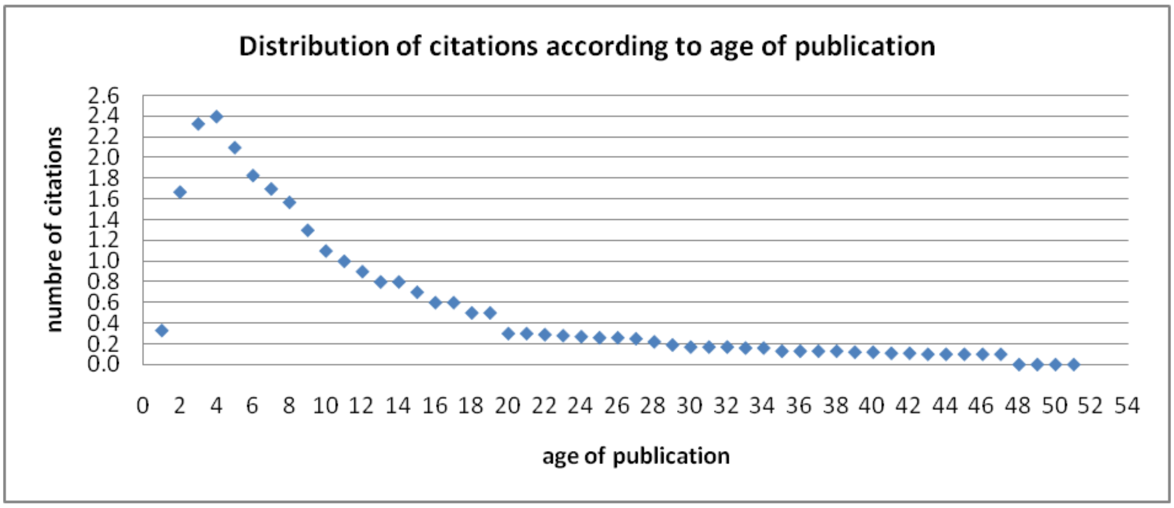

Figure 6.9. Distribution of citations according to age of a publication

In the simulation model, after being published a paper stays in three stocks in its life time. The time parameters which are called *Obsolete Time* and *Mature Time* determines for how long a paper stays in a stock and receives citation. In order to obtain the "age distribution of a paper" shape in Figure 6.9, a simplified model consisting of the three publication stocks and a citation stock is constructed. The simplified model is shown in Figure 6.10.

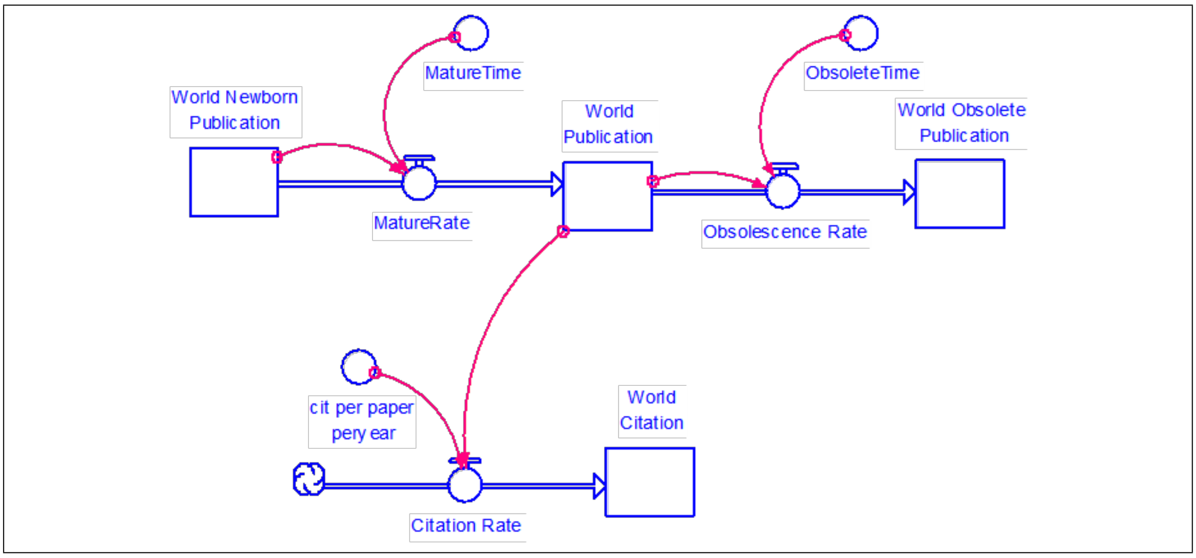

Figure 6.10. Simplified World-Publication Model

In the model in Figure 6.10, *Mature Time* and *Obsolete Time* and *cit per paper per year* parameters are found by trial and error such that they will provide a behavior which is similar to the age distribution of citations of a paper. When we initialize the model with 100 papers (100 papers in the World Newborn Publication stock) we expect the resulting numbers to be 100 times of 1 paper's results.

With the parameter set shown in the Table 6.3, the behavior shown in Figure 6.11 is obtained. The behavior obtained in the model is close enough to the behavior observed in real data.

Table 6.3. Parameter set which matches the behavior of distribution of citations according to age of world publications

New Born Papers initial	**1**
Other stock initials	0
Obsolete T	9 years
Mature T	1.8 years
Cit/ paper/year	3.4

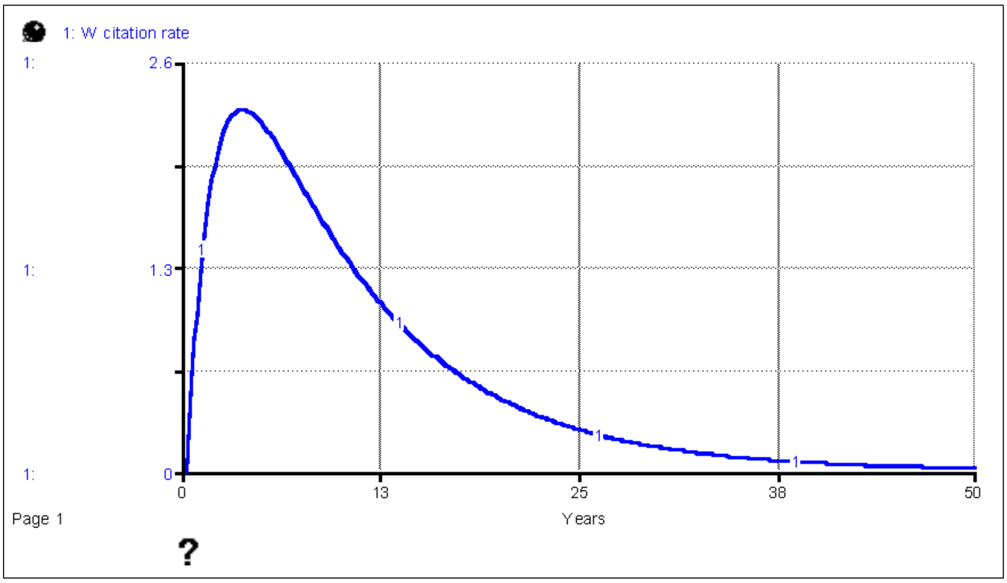

Figure 6.11. Distribution of citations according to age of a publication in the model

As a supplementary validation information, the following data are given. Lariviere et all (Lariviere et all) provides in the paper that, in Natural Sciences and Engineering, in 2004;

Median age of cited literature= 7.1

Average age of cited literature= 11.5

Price index (percentage of 5 years or younger references) = 38 percent

# of references per article= 28

The model gives exactly the same numbers for the age of cited literature with the given parameter set.

Remember that, the behavior of references and citations are assumed the same. However, the numbers of references and citations do not need to be the same. We employ the *Mature Time* and *Obsolete Time* parameters found in this part but *citation per paper per year* parameter is found in section 6.1.4.1with citations data.

6.1.5.1. *Obsolete Time* & *Mature Time* for BU Engineering Faculty. All of the publications written by BU Eng Faculty are obtained from WOS. Number of citations received by those publications each year are obtained.

The publications are grouped into 3 quality classes; A, B and C. The BU Engineering Faculty publications are listed from the highest to the lowest according to the number of citations received in the first 8 year after being published. The publications which receive more than 14 citations (two times the world average) are assumed to be A type / high quality, the publications which receive less than 14 but more than 4 citations (half of the world average) are assumed to be B type / medium quality, and the publications which receive less than 4 citations are assumed to be C type /low quality publications. The quality boundaries calculated with the world data are shown in Table A.3.

Since the purpose of this study is to see the behavior of citations versus age of publications, old papers are required. Therefore, only the publications of years 1985-2000 are examined.

Publications are observed in three different intervals.

First of all, the publications of year 1995-2000 are observed. This publication group is more up-to-date. The purpose of selecting this interval is that it provides an insight about how long it takes to reach the peak number of citations. The number of citations versus age of publications of 1995-2000 publications is in Figure 6.12.

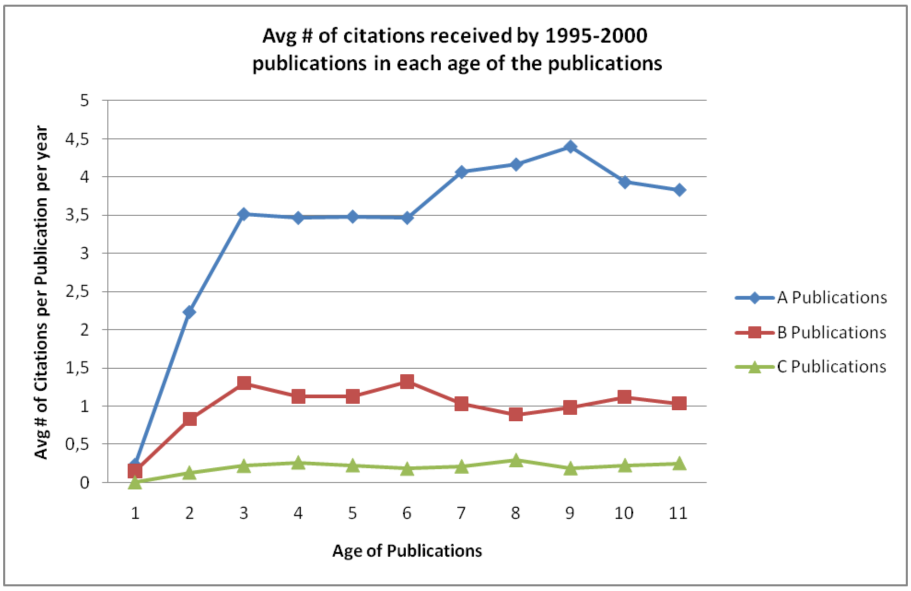

Figure 6.12. Number of citations versus age of publications for 1995-2000 publications

Secondly, in order to see the long run behavior, older publications are observed. The number of citations versus age of publications of 1985-1995 publications is in Figure 6.13.

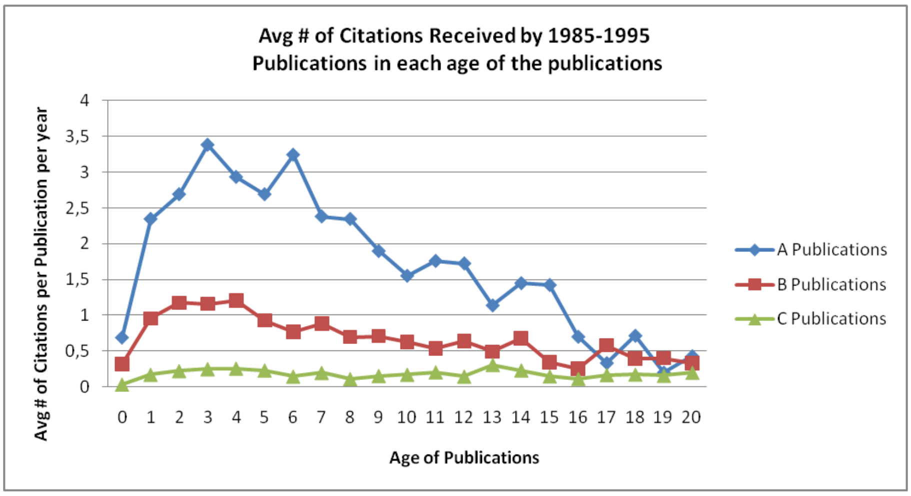

Figure 6.13. Number of citations versus age of publications for 1985-1995 publications

To see how long the peak continues, the papers of years 1991-1996 are observed. The number of citations versus age of publications of 1991-1996 publications is in Figure 6.14.

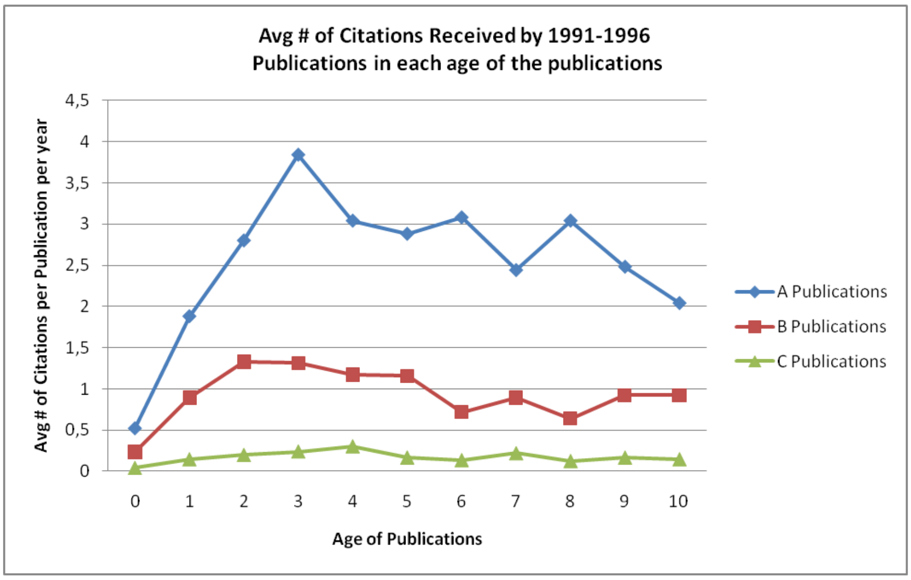

Figure 6.14. Number of citations versus age of publications for 1991-1996 publications

When the three figures are examined, the following conclusions are drawn. For *A type publications*, the peak occurs in the 3rd year. The approximate number of citations in the 1st year is 2.75, in the 2nd year 3.75, in the 3rd year 4.00, in the 4th year 3.75. In the 10th year, according to 1985-1996 data the approximate number of citations is 1.6; according to 1991-1996 data, it is 2.4 and according to 1995-2000 data, it is 3.75. We adopt the number as 3.5. In the 20th year approximate number of citations is 0.4.

For *B type publications*, the peak occurs in between 2nd and 3rd year. The average number of citations in the 1st year is 0.8, in the 2nd year 1.3, in the 3rd year 1.3, in the 4th year 1.2. In the 10th year according to 1985-1996 data the approximate number of citations is 0.6; according to 1991-1996 data, it is 0.9 and according to 1995-2000 data, it is 1. We adopt the number as 1. In the 20th year approximate number of citations is 0.35.

For *C type publications*, the peak occurs in the 4th year. The average number of citations in the 1st year is 0.15, in the 2nd year 0.2, in the 3rd year 0.26 and in the 4th year it is between 0,28 and 0,30. After that, the number decreases to 0.2 and stays there for a very long time.

To see the data in detail, each year's publications are shown in big Figure A.1.

The simplified model constructed for world data is used for Bogaziçi Engineering Faculty publications as well which is shown in FigureA.7.

Mature Time, *Obsolete Time* and *cit per publication per year* parameters are found by trial and error such that they provide a behavior which is similar to the age distribution of citations of Bogaziçi Engineering Publications. The model is initialized with 1 paper (1 paper in the *Newborn Publication* stock).

The parameter set used in the model which gives the intended results is given in Table 6.4.

Table 6.4. The parameter set used in the model for three publication classes

	A Publications	**B Publications**	**C Publications**
Mature Time	1.4 years	1.2 years	1.8 years
Obsolete Time	18 years	18 years	20 years
Cit per pub per year	5	1.6	0.35

The resulting behavior in a 50 year time window is shown in Figure 6.15.

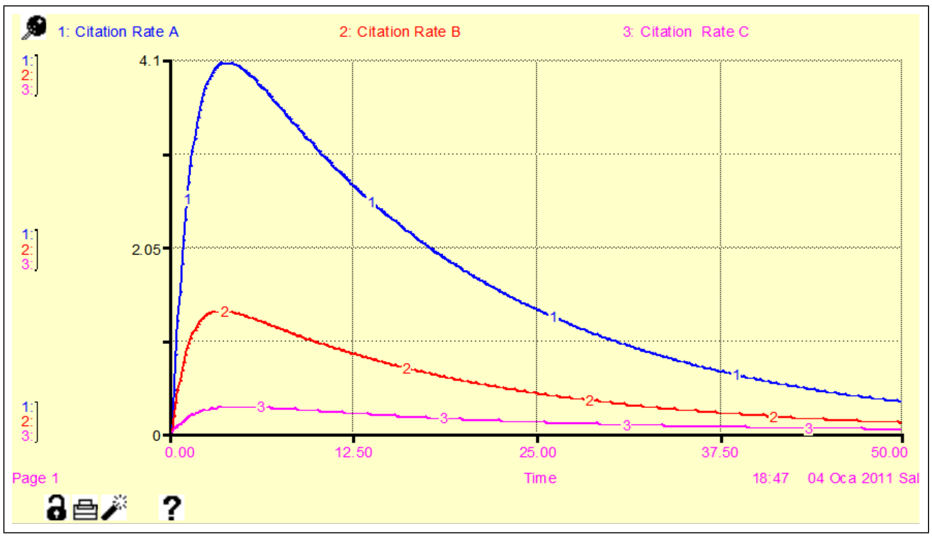

Figure 6.15. Number of citations versus age of publications in the model

Mature Time and *Obsolete Time* parameters are providing the intended citation behavior. These parameters are used in the simulation model as found in this model. However, the citation rates are changing in time. Therefore, *cit per pub per year* parameter is going to be calculated again in a following section with citation data.

The real data of 1995-2000 is imitated with the A-B-C classification. In those years 63 *A type publications*, 100 *B type publications* and 137 *C type publications* have been published. The model is initialized with these numbers of publications. The real citation data is shown in Figure 6.16. Citation rates obtained from the simulation model are shown in Figure 6.17. The behaviors are satisfactorily close.

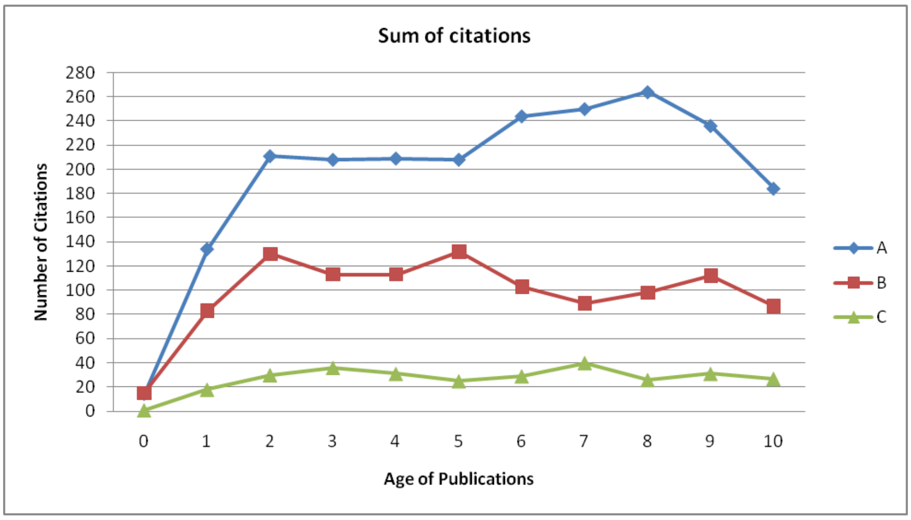

Figure 6.16. Sum of citations received in every age of the 1995-2000 publications

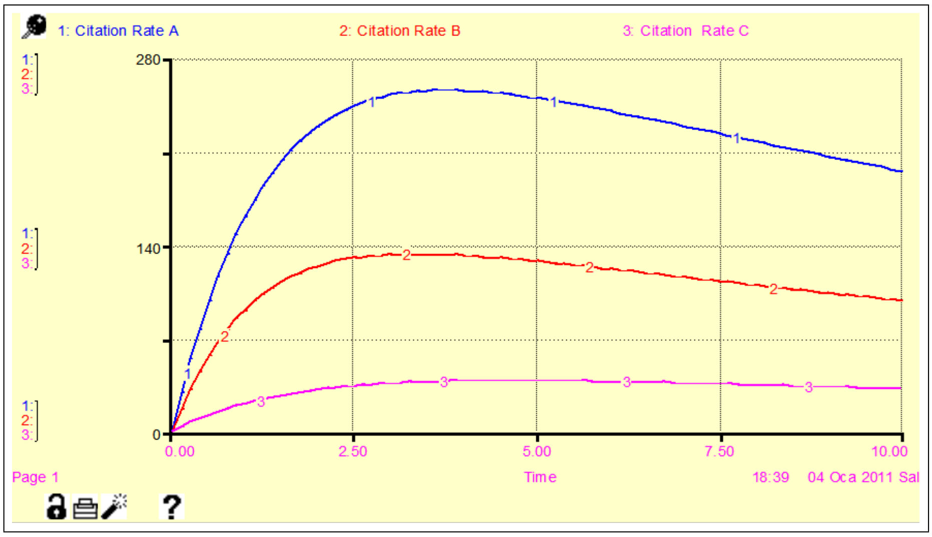

Figure 6.17. Sum of citations received in every age of the publications in the model.

6.1.5.2. Initializing Publication Stocks. The publications published by BU Engineering Faculty from years 1981 to 2010 is obtained from Web of Science. The publication data is shown in Appendix A.

6.1.5.3. Classification of the data according to quality. The publications that were published from year 1981 to 2006 are classified into A, B, C quality classes according to the number of citations received in their first 8 years. For the publications which are younger than 8 years, the classification is done according to citations received up to 2010, without considering number of years. For classification, world data is used as the benchmark. "Quality A" boundary is two times the first eight-year citations of an average world paper. If the number of first eight year citations of a publication is higher than two times the first eight year citations of an average world paper, that publication is called an *A type publication*. "Quality C" boundary is half of the first eight-year citations of an average world paper. If the number of first eight year citations of a publication is lower than half of the first eight year citations of an average world paper, that publication is called a *C type publication*. A publication, whose first eight year citations is between the mentioned boundaries, is called a *B type publication*.

The quality boundaries are changing in years. For instance, an average world publication published in year 1981 received 5.6 citations in its first eight years. If a BU paper published in 1981 received 15 citations in its first eight years, it is called an *A type publication* because 15 is more than two times of 5.6. If it received 5 citations in its first eight years, it is considered as a *B type publication* because 5 is higher than half of 5.6. On the other hand, an average world publication published in year 2000 received 11.54 citations in its first eight years. So, if a BU paper published in year 2000 received 15 citations in its first eight years, it is called a *B type publication* because 15 is less than two times of 11.54. If it received 5 citations in its first eight years, it is considered as a class *C type publication* because 5 is less than half of 11.4. Table A.3 shows the quality boundaries for every year from year 1981 to 2006.

By using the model (Figure 6.18), which is a simplified version of the whole model, the publication stocks are initialized. *Publish Rate A*, *Publish Rate B*, and *Publish Rate C* is given to the model as exogenous variables from year 1981 to 2006. From the values created by this model, 1995 values of the publication stocks are taken and given to the simulation model as the initial stock values. The initial values are provided in Table 6.5.

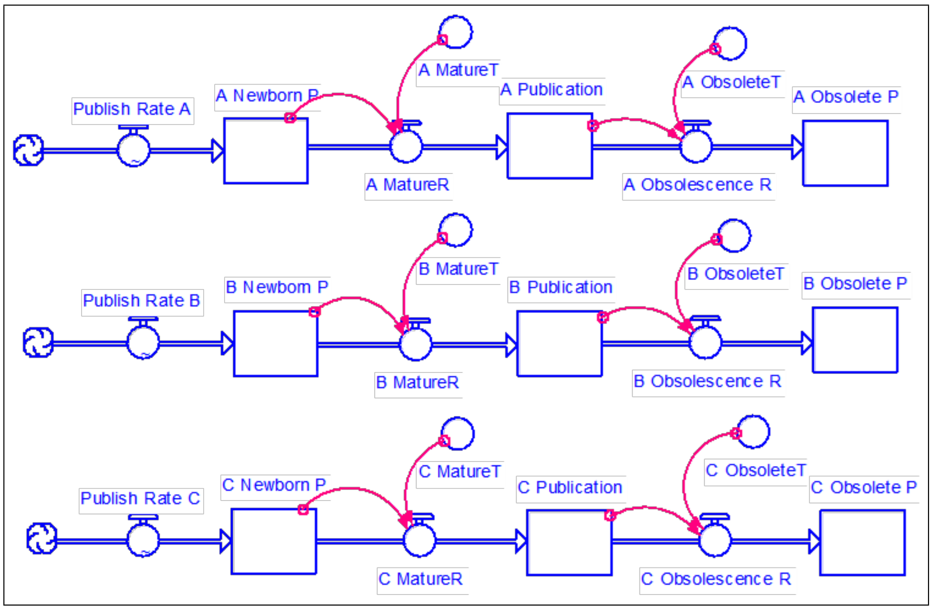

Figure 6.18. Simplified Publication model

Table 6.5. The initial (1995) values of the publication stocks.

Year	**1995**
Newborn Publication A	5
Publication A	19
Newborn Publication B	16
Publication B	59
Newborn Publication C	25
Publication C	55
Obsolete Publication	31

6.2. Research Time Sector

6.2.1. Description of the Structure

Faculty members have various kinds of jobs like; administrative jobs, attending lectures, making research etc. In this model we are dealing with the research activities of the faculty. The *Research Time* stock represents average time of the faculty members that is devoted to research activities. It is assumed that those research activities end up with writing academic papers and submitting those papers to academic journals.

Research Time is not constant. It increases or decreases depending on the publication pressure felt by the faculty members. The change cannot be sudden. In order to add a time delay to research time changes, *Research Time* is modeled as a stock variable. The stock flow diagram of *Research Time* sector is in Figure 6.19.

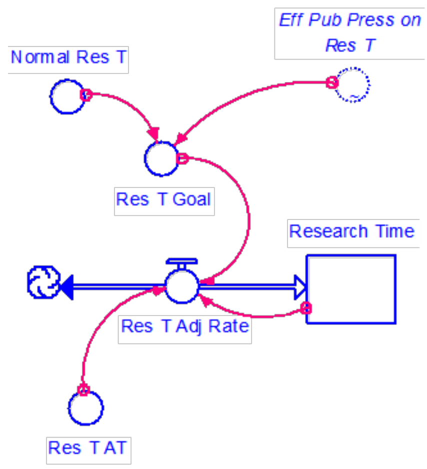

Figure 6.19. Stock flow diagram of "Research Time" sector

Normal Research Time is determined to be 0.3 in the model. *Research Time* changes according to effect of publication pressure. When the *average number of publications per faculty per year* is below the world average, faculty members feel publication pressure and they increase their *research time*. When the a*verage number of publications per faculty per year* is above the world average, *research time* decreases to below the normal level. The effect function is shown in Figure 6.20.

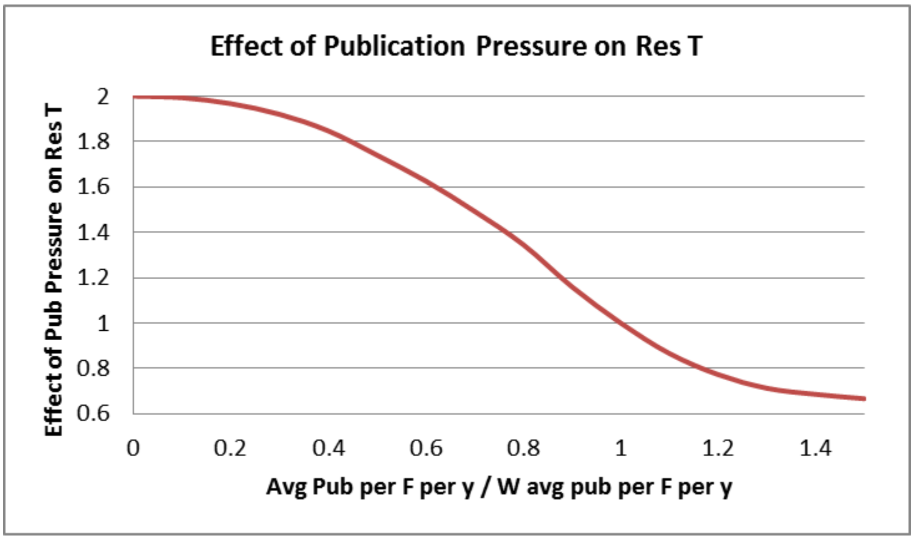

Figure 6.20. Effect of publication pressure on Research Time

Research Time Adjustment Time equals to 8 years, which means that it takes 8 years to adjust the time that is devoted to research activities. Initial *Research Time* is set 0.2.

$$ResearchTime(t) = ResearchTime(t - dt) + (ResTAdjRate) * dt \tag{6.12}$$

Research Time stock is fed by a biflow; *Research Time Adjustment Rate.*

$$ResTAdjRate = (ResTGoal – ResearchTime)/ResTAT \tag{6.13}$$

6.2.2. Initializing the stock:

We know the *Publish Rate*s in each quality category in each year. *Paper submitted stocks* should provide those *publish rates.* The flow *Paper Writing Rate A/B/C* feed the *Paper submitted stocks* and *Research Time* directly affects the *paper writing rates.* Initial *Research Time* is selected such that, it approximately gives the required *Paper Writing Rates* and finally provides the required *publish rates.*

$$PaperWritingRateA/B/C = Faculty * EffSkillonPub*$$
$$* ResearchTime * \frac{fractofResTforA/B/C}{requiredTA/B/C} \quad (6.14)$$

We know *Faculty*, *Eff of Skill on Publication*, *fraction of Research Time for A/B/C Research* for years 1995 to 2006 and *required time A/B/C*. By using the parameters we know, initializing *Research Time* with 0.2 gives the intended *Paper Writing Rate A/B/C* values. The change in the *Research Time* and the values of *Effect of Publication Pressure on Research Time* parameters for the first eleven years are seen in Figure 6.21.

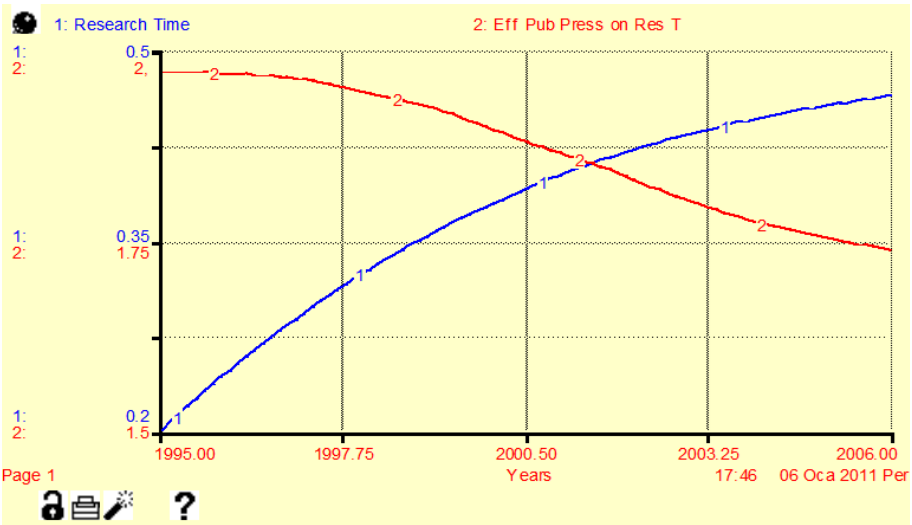

Figure 6.21. Research Time and Effect of Publication Pressure on Research Time between years 1995-2006.

6.3. Publication and Citation Pressures Sector

6.3.1. Background Information.

For measuring quality with respect to citation, *impact factor* is a common accepted metric. *Impact factor* is originally defined with the name *journal impact factor* for having an insight about the quality of the journals. *Journal impact factor* is described in Section 6.1.1. For measuring the quality of the publications, *impact factor,* which can be defined as number of citations per publication, is used widely. In this model, the citation performance of the researchers are quantified by *impact factor.*

6.3.2. Assumptions

It is assumed that faculty uses two main research performance measures. The first one is *average number of publications per faculty per year.* The second one is *average number of citations received per publication*. These two performance measures are compared with reliable benchmarks. World data is chosen to be the benchmark. *Average number of publications per faculty per year* in engineering fields in recent years in the world is used to measure publication performance of the faculty. The average number of citations received by the publications in engineering fields in the world is used to measure the citation performance of the faculty. If the *average number of publications per faculty per year* is less than the world average, faculty members feel a publication pressure. On the other hand, if the *average number of citations per publication* is less than the world average, faculty members feel a citation pressure. The higher the gap between faculty's and the world's performance measures, the stronger the pressure felt by faculty members.

An assumption is that, it is in the faculty's hands to make decisions about how to distribute their *research time* between research activities. The main dynamic of the model comes on stage at this decision time. Under the publication and citation pressures, faculty members decide on writing *A, B or C type papers.* It is assumed that, if there is publication pressure on the faculty, they tend to ignore quality and try to write as many papers as they can. This pressure pushes them to write *C type papers* because *C type papers* are easy to write and they are written in a short time. They tend to use their *research time* more in writing *C type papers* and less in writing *A type papers.* On the other hand, if there is citation pressure, quality will be indispensable because, only high quality publications receive high numbers of citations. Citation pressure will push the faculty members to write *A type papers* which are not easy to write, require a long time but get high number of citations. In the absence of any pressure, *B type papers* are written. If both of the pressures are felt at the same time, faculty members try to make both *A* and *C type papers* to deal with both of the pressures.

6.3.3. Description of the Structure

The stock flow diagram of the Publication and Citation Pressures is seen in Figure 6.22.

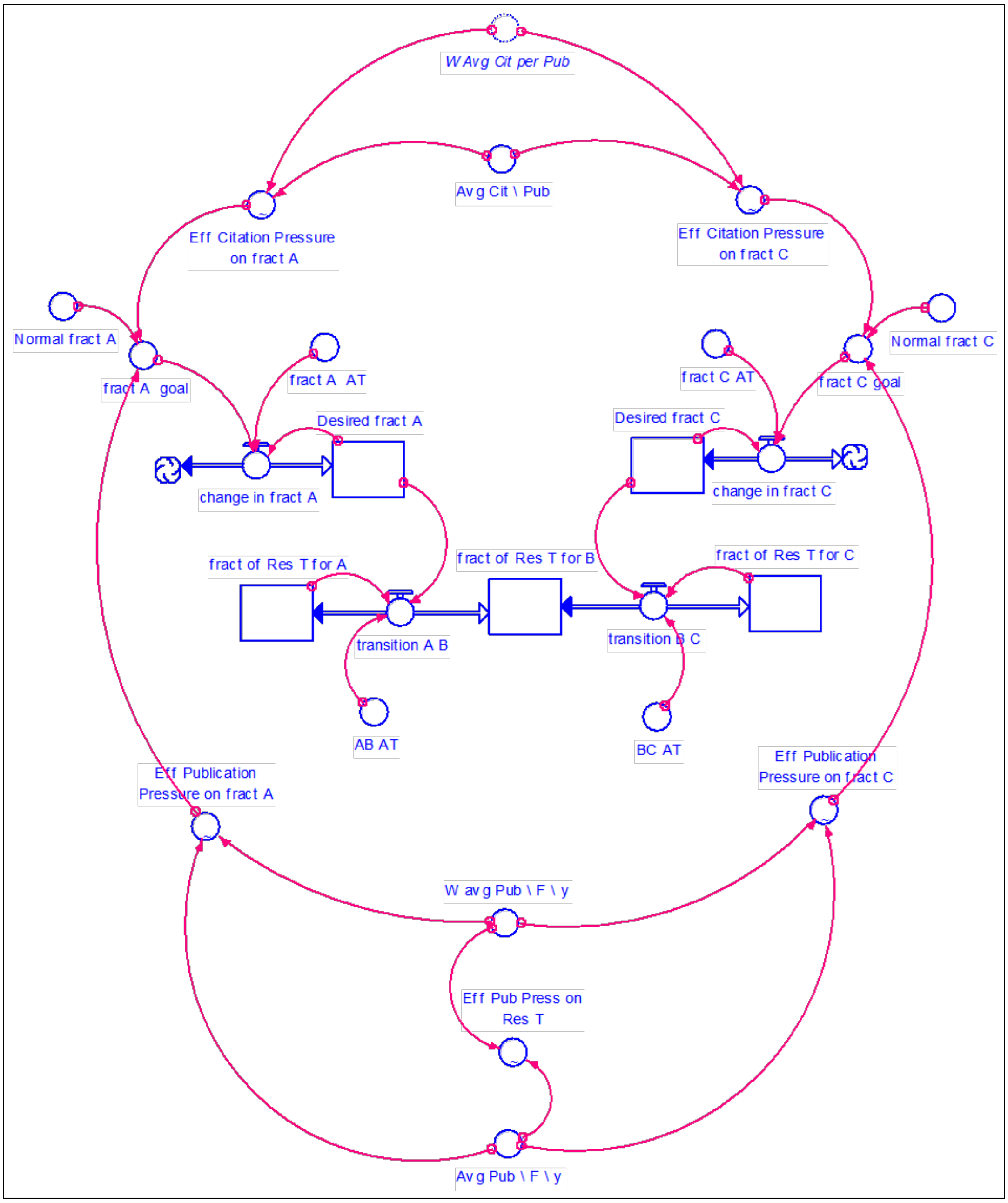

Figure 6.22. Stock flow diagram of Publication Pressure and Citations Pressure sector

<u>6.3.3.1. Citation Pressure.</u> Citation Pressure occurs by comparing *average number of citations per publication* of the faculty with *average number of citations per publication* in the world.

The variables used in finding *Average Citation per Publication* is shown in Figure 6.23.

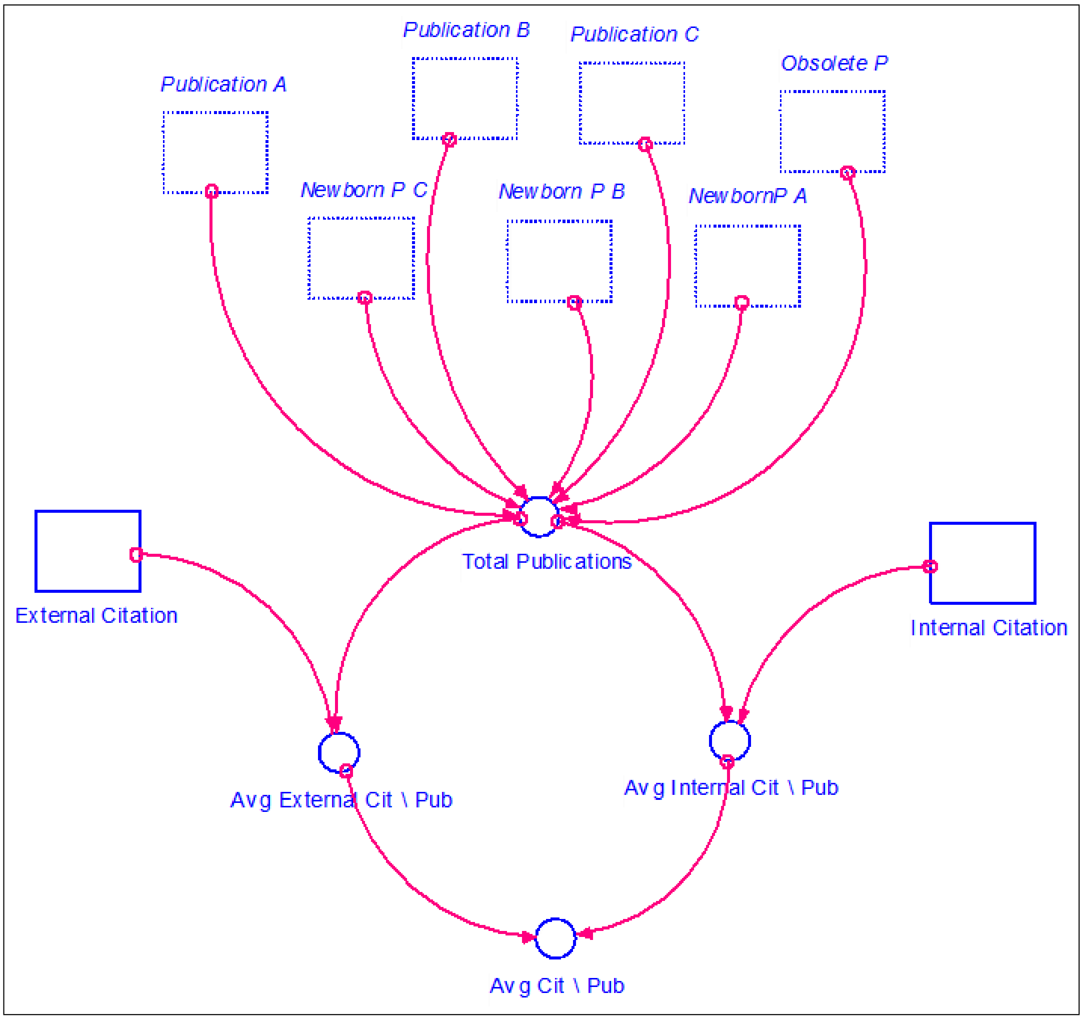

Figure 6.23. Average citation per publication in the model

$$TotalPublications = NewbornPublicationA + NewbornPublicationB + \\ + NewbornPublicationC + PublicationA + PublicationB + \\ + PublicationC + ObsoletePublication \quad (6.15)$$

$$AverageExternalCitationsperPublication = \frac{ExternalCitation}{TotalPublications} \quad (6.16)$$

$$AverageInternalCitationsperPublication = \frac{InternalCitation}{TotalPublications} \quad (6.17)$$

$$AverageCitationsperPublication = AverageExternalCitationsperPublication+ \\ + AverageInternalCitationsperPublication \quad (6.18)$$

The parameter *world average citation per publication* is found in Section 6.1.4.1.

The function *effect of citation pressure on Fraction A* is seen in Figure 6.24. When *average number of citations per publication* over *world average citations per publication* ratio equals to 1, there is no citation pressure effect on f*ract of Res t for A*. When the ratio is lower than 1, the effect formula increases *fract of Res t for A* and when the ratio is below 1, the effect formula decreases *fract of Res t for A*.

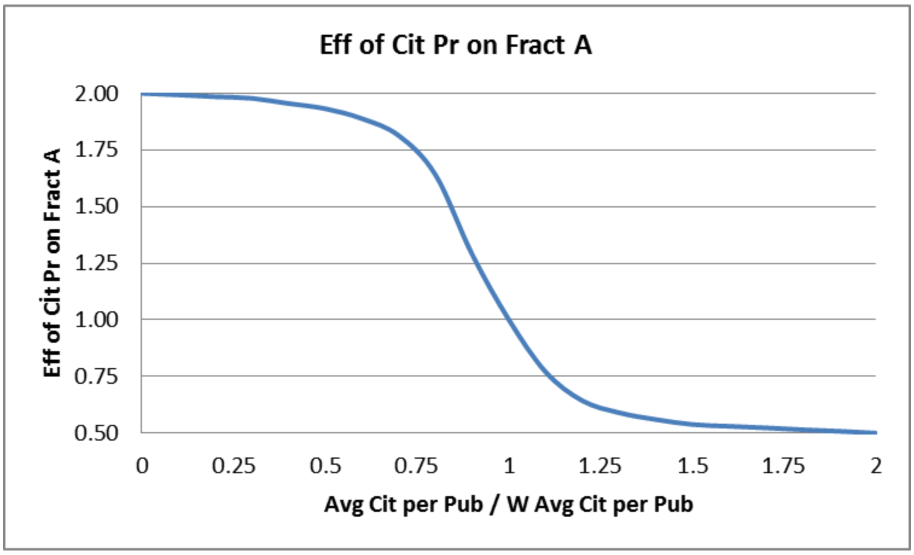

Figure 6.24. Effect of citation pressure on fraction of research time devoted to A research

The function *effect of citation pressure on Fraction C* is seen in Figure 6.25. When *average number of citations per publication* over the *world average citations per publication* ratio equals to 1, there is no citation pressure effect on *fract of Res t for C*. When the ratio is lower than 1, the effect formula decreases *fract of Res t for C* and when it is above 1, the effect formula increases *fract of Res t for C*.

Effect of citation pressure on *fract of Res t for A* is stronger than that on *fract of Res t for C*.

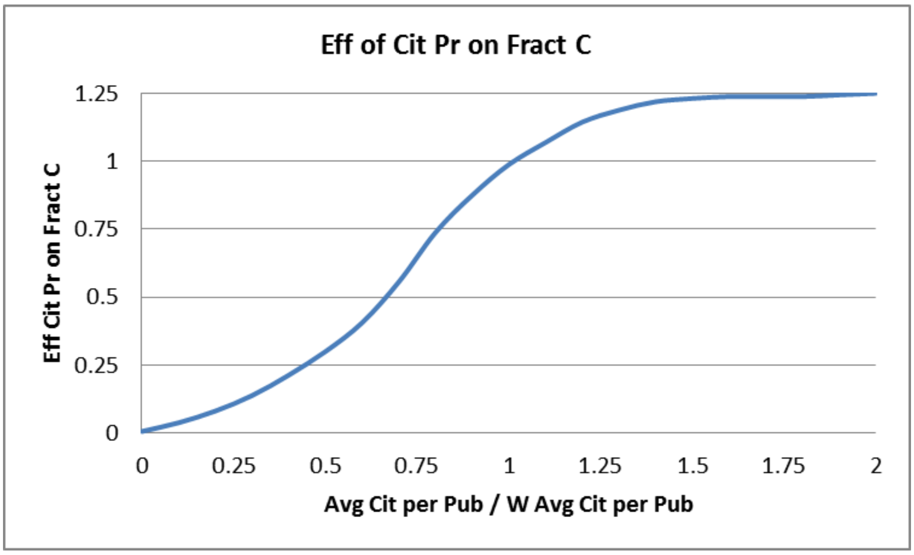

Figure 6.25. Effect of citation pressure on fraction of research time devoted to C research

<u>6.3.3.2. Publication Pressure.</u> The variables used in finding *Average Publications per Faculty per year* is shown in Figure 6.26. Three year moving average method is used for calculating this parameter. A conveyor stock, which keeps the publications waiting for three years in it and then lets them go, is used.

$$AveragePublicationsperFacultyperyear = \frac{TotalPublicationsin3years}{(year * Faculty)} \quad (6.19)$$

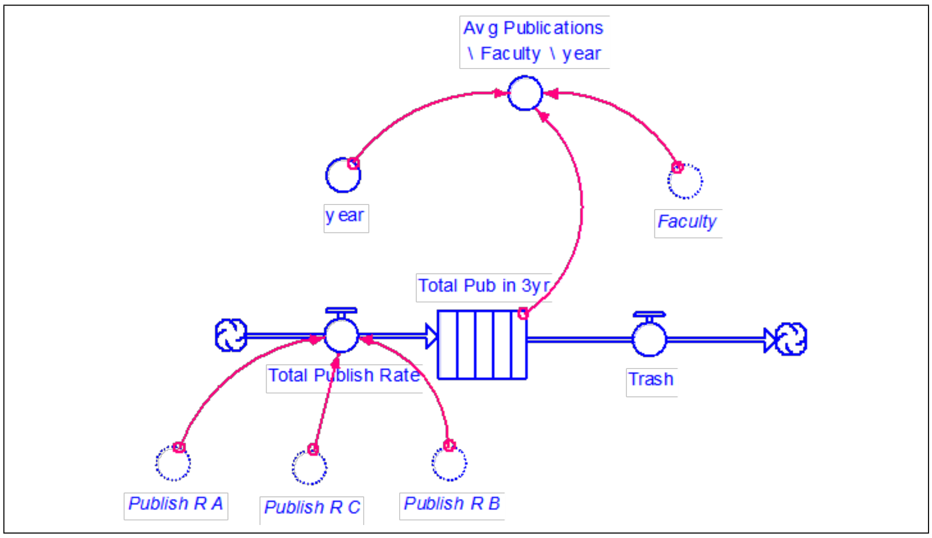

Figure 6.26. Average publications per faculty per year

World *Average Publications per Faculty per Year* equals to 1.57. This number is obtained from the study (Bilge et al., 2007). It is assumed to stay the same throughout the simulation period.

The function *effect of publication pressure on Fraction C* is seen in Figure 6.27. When *average number of publications per faculty per year* over *world average number of publications per faculty per year* equals to 1, there is no publication pressure effect on f*ract of res t for C*. When the ratio is lower than 1, the effect formula increases *fract of Res t for C* and when it is above 1, the effect formula decreases *fract of Res t for C*.

The function *effect of publication pressure on Fraction A* is seen in Figure 6.28. When *average number of publications per faculty per year* over *world average number of publications per faculty per year* equals to 1 there is no publication pressure effect on *fract of res t for A* . When the ratio is lower than 1, the effect formula decreases *fract of res t for A* and when it is above 1, the effect formula increases *fract of res t for A*.

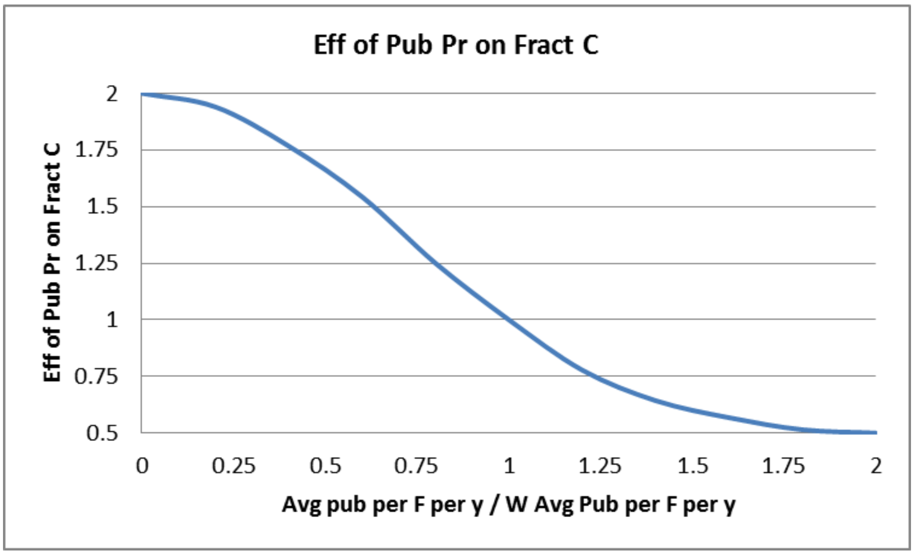

Figure 6.27. Effect of publication pressure on fraction of research time devoted to C research

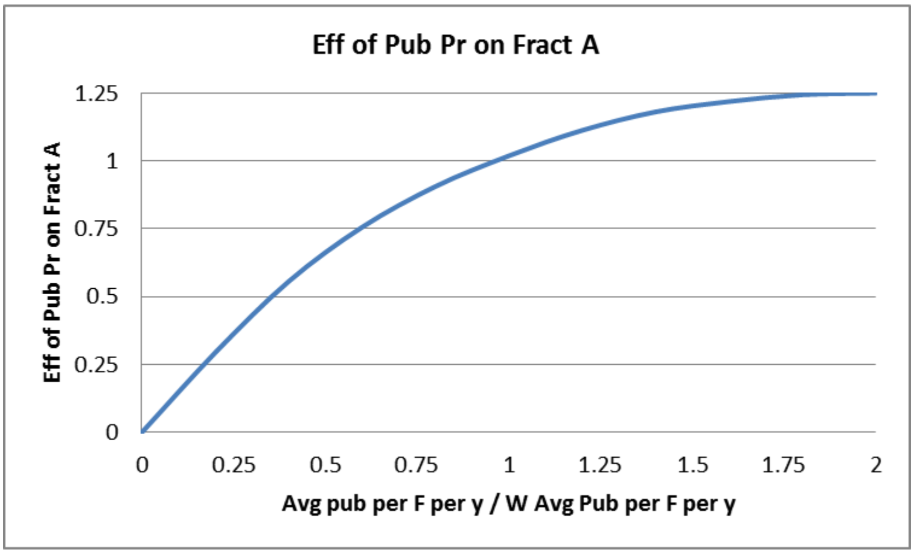

Figure 6.28. Effect of publication pressure on fraction of research time devoted to A research

6.3.3.3. Stocks. Second order information delay structure is used for modeling the research time allocation stocks. Higher order information delays are used in cases where the delay between the actual state of a system and the decisions that alter it involves multiple stages. There may be administrative delays, cognitive and decision-making delays – it takes time for decision makers to revise their beliefs and further time to finalize a judgment and act on it (Sterman, 2000). In this model, second order delay gives a satisfactory behavior.

In the second order information delay structure, *Desired fract A/C* stock is the first delay and *fract of Res T for A/C* stock is the second delay.

The equations are as follows:

$$FractAgoal = NormalfractA * EffCitationPressureonfractA* \\ * EffPublicationPressureonfractA \quad (6.20)$$

$$FractCgoal = NormalfractC * EffCitationPressureonfractC* \\ * EffPublicationPressureonfractC \quad (6.21)$$

In these equations, it is guaranteed that sum of *Fract A goal* and *Fract C goal* does not exceed 1 when the two effect functions are multiplied.

In the Figure 6.29, some extreme condition tests on *fract A goal* and *fract C goal* are performed. The extreme conditions are no publication pressure with high citation pressure, no citation pressure with high publication pressure, equal citation pressure and publication pressure. Some values of pressures in between are also tested and provided in the figure. On the x axis, *average number of citations per publication over world citations per publications* and *average number of publication per faculty per year over world publications per faculty per year* values are given. The values correspond to the strength of citation pressure and publication pressure. The cylinders represent the percentages calculated by using *fract A goal* and *fract C goal. fraction B* is calculated by subtracting sum of *fract A* and *fract C* from 1, since the percentages should sum up to 1. This figure shows the resulting values of type A, B and C fractions of research time under extreme conditions. The first cylinder shows that, when there is no citation pressure and publication pressure, research time is allocated 100 percent to *B type research*. Second cylinder shows that, when when there is no citation pressure but a very high publication pressure, research time is allocated as, 60 percent to *A type research* and 40 percent to *B type research*. The rest of the figure can be read in the same way.

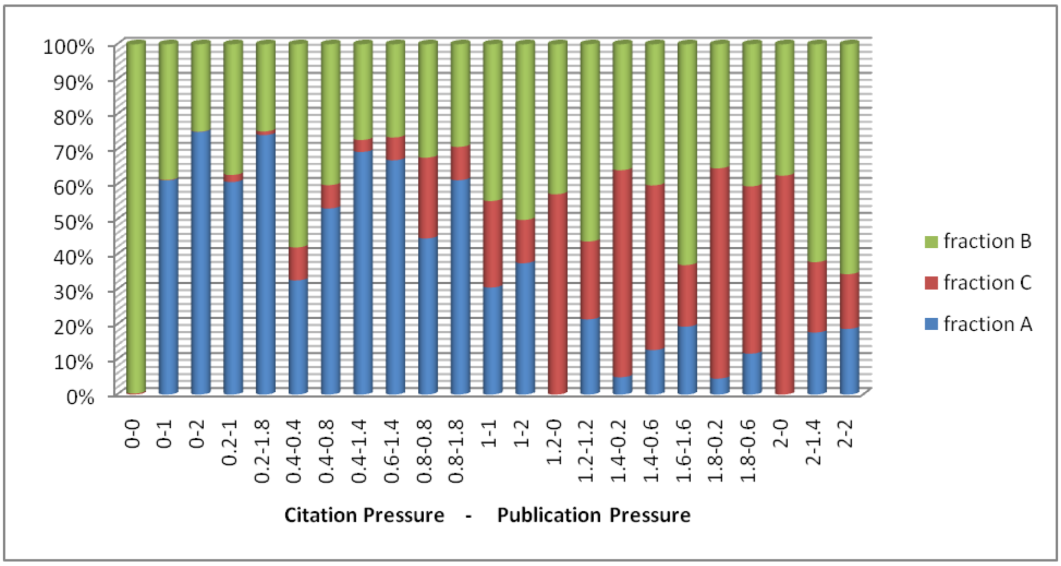

Figure 6.29. Extreme condition tests on research time allocation

The equations of the stock flow structure are shown below:

$$DesiredfA(t) = DesiredfA(t - dt) + (changeinfA) * dt \tag{6.22}$$

$$ChangeinfA = (fAgoal - DesiredfA)/fAAT \tag{6.23}$$

$$DesiredfC(t) = DesiredfC(t - dt) + (changeinfC) * dt \tag{6.24}$$

$$ChangeinfC = (fCgoal - DesiredfC)/fCAT \tag{6.25}$$

Fract of Res T for A/B/C stocks are like a close circuit. *Transition A B* and *Transition B C* flows which are bi flows connect those three stocks.

$$FractofResTforA(t) = fractofResTforA(t - dt) + (-transitionAB) * dt \tag{6.26}$$

$$FractofResTforB(t) = fractofResTforB(t - dt) + \\ + (transitionAB–transitionBC) * dt \tag{6.27}$$

$$FractofResTforC(t) = fractofResTforC(t - dt) + (transitionBC) * dt \tag{6.28}$$

$$TransitionAB = (fractofResTforA–DesiredfA)/ABAT \tag{6.29}$$

$$TransitionBC = (DesiredfC–fractofResTforC)/BCAT \tag{6.30}$$

6.3.4. Parameter Estimation

We know the *publish rates* for each quality type of papers for years 1981-2006. The *publish rates* and the calculations of *fract of Research time for A/B/C research* are shown in Table A.4. In the calculations, number of faculty members are increasing every year. *Required time for A papers* is 0.8, r*equired time for B papers* is 0.4 and *required time for C papers* is 0.2.

The values of *fract of Research Time for A/B/C research* from years 1995 to 2006 is provided in Figure 6.30 to observe the values. In Figure 6.31, values of *fract of research time for A/B/C research* obtained with a 3 year moving average approach are shown. It is seen that, *fract of research time devoted to B research* is higher than *fract of research time devoted to A research* and *fract of research time devoted to C research.* Research time devoted to A research is a little higher than to C research. But the fractions are almost stable for the years 1995 to 2006. There is a slow decrease in *ract of research time devoted to B research.* In the last three years, (2003 - 2006) *fract of research t for A* has been increasing and *fract of research t for C* has been decreasing.

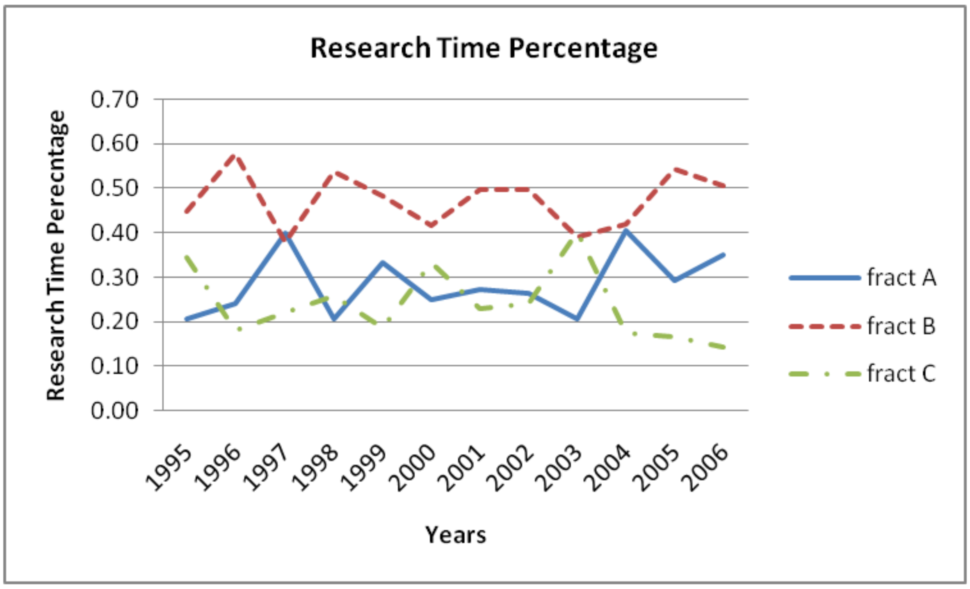

Figure 6.30. Research time percentages

Keeping the data analysis in mind, initial values of the stocks and some of the relate parameters are determined as shown in Table 6.6.

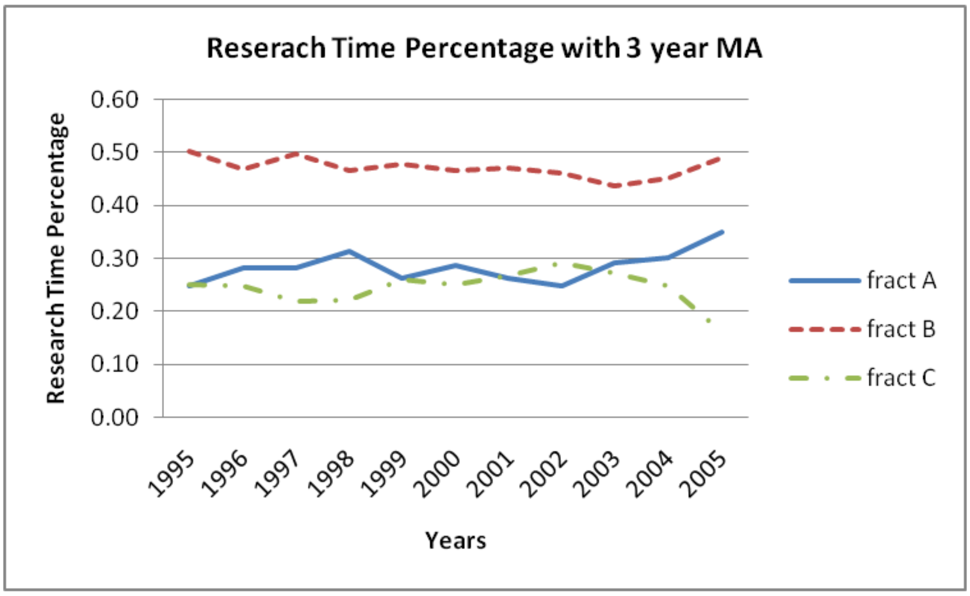

Figure 6.31. Research time percentages with 3 year MA

Table 6.6. Initial values of Research time

Normal fract A	0.3
Normal fract B	0.25
Desired fract A	0.3
Desired fract B	0.25
Fract of Res T for A	0.29
Fract of Res T for B	0.47
Fract of Res T for C	0.24

Adjustment Time parameters are selected according to assumptions. *Fract A AT* and *Fract C AT* are 3 years. *AB AT* and *BC AT* are 1 year.

6.4. Skill Sector

6.4.1. Background Information

Skill level of faculty is a combination of many qualities of the faculty. Experience, financial position, accessibility to research materials are some of those qualities. In order to keep the model simple, this variable is included in the model as an exogenous variable. *Skill* level has a positive effect on *publish rate*. It can be said that thanks to having a high level of skill, required time for writing a paper is short, so it is possible to write more papers in less time. Skill level has a positive effect on number of citations received as well.

6.4.2. Assumptions

Skill level of the faculty has a positive effect on both of the citation types. Although each type of paper is submitted to the related type of journal, like a class *A type paper* to *A type journal*, it can not be said that all the *A type papers* in an *A type journal* receive the same number of citations. Skill level provides this difference in citation receiving rates between two *A type papers* in an *A type journal*.

6.4.3. Description of the Structure

Skill is modeled as an exogenous variable. Scale of *skill* level is 0-100. The *skill* level of 50 is chosen as normal *skill* level. If the *skill* level of faculty is 50, there is no increasing or decreasing effect of *skill* on neither publications nor citations (Figure 6.32).

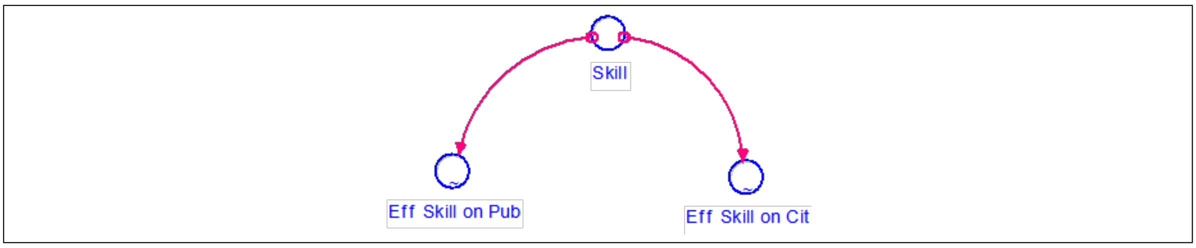

Figure 6.32. Skill sector in the model

6.4.3.1. Effect of Skill on Publications. This function has an effect on *Paper Writing Rates*. The equation of *paper writing rate* is below:

$$PaperWritingRateA/B/C = Faculty * EffSkillonPub* \\ * ResearchTime * \frac{fractofResTforA/B/C}{requiredTA/B/C} \quad (6.31)$$

The effect function is provided in Figure 6.2.

Skill has the power to increase the *Paper writing rates* at most two times. If *skill* level is very low, then the *paper writing rates* decrease to at most half of the rate.

6.4.3.2. Effect of Skill on Citations. This function has an effect on *External Citation Rate* and *Internal Citation Rate.* The equations of the rates are below:

$$ExternalCitRate = (PublicationA*ExtCit\backslash P\backslash YA+PublicationB*ExtCit\backslash P\backslash YB+ \\ + PublicationC * ExtCit\backslash P\backslash Y C) * EffSkillonCit * EffReponExtCit \quad (6.32)$$

$$InternalCitRate = (PublicationA*IntCit\backslash P\backslash YA+PublicationB*IntCit\backslash P\backslash YB+ \\ + PublicationC * IntCit\backslash P\backslash Y C) * EffSkillonCit * EffofPublishRate \quad (6.33)$$

The effect function is provided in Figure 6.33.

Skill has the power to increase the *External Citation rate* and *Internal Citation rate* at most two times. If *skill* level is very low, then the *external* and *internal citation rates* decrease to at most half of the rates.

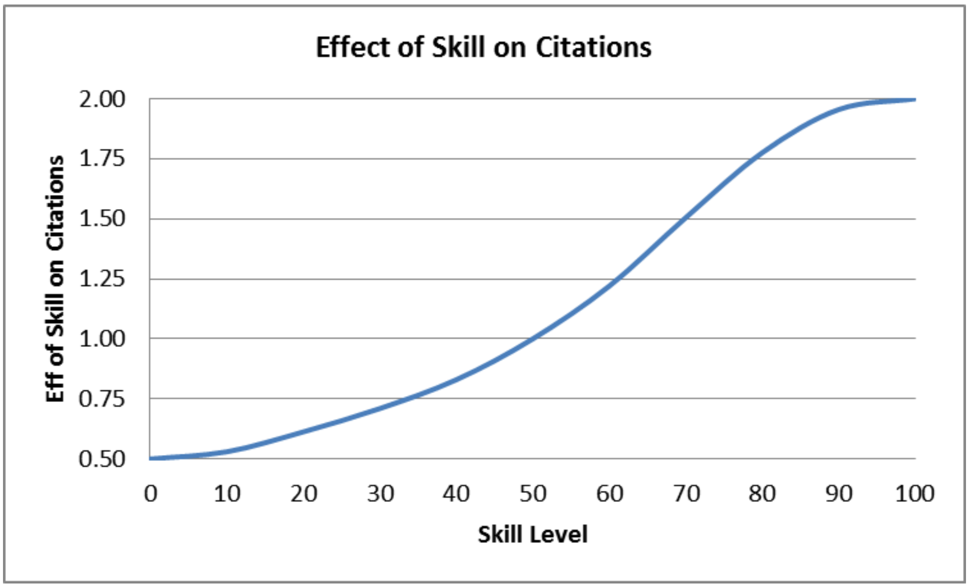

Figure 6.33. Effect of Skill on Citations

6.5. Reputation Sector

6.5.1. Background Information

To have reputation in academic world means to be known for making good research. This good esteem makes your publications read by other researchers. Other researchers who read your publications give citations to your publications. The more citations your publications receive, the more visible you are in the academic world. Therefore, *average number of citations per publication* and reputation has a direct effect on each other.

The difference in the definitions of *external citations* and *internal citations* should be emphasized here. *External citations* are received from researchers out of the university. Visibility, namely *reputation* of the faculty is essential in receiving *external citations*. However, *internal citations* are received from the colleagues of the author of a publication. The faculty members know each other and are informed about each other's publications. *Reputation* is not essential in receiving *internal citations*.

Although *reputation* does not help receiving *internal citations*, *average number* *of internal citations per publication* has positive effect on *reputation.* The more the *average number of internal citations per publication*, the more the *average number of citations per publication.* Most of the time impact calculations are done by considering sum of the citations without checking whether the citations are external or internal. The before mentioned visibility in the academic world is twofold indeed. One is being known with your name by other people. The other one is being in the list of good researchers. If you have a high *impact factor,* you are considered as a productive, well-publishing researcher no matter the source of the citations is. Knowing that positive effect of impact factor in being in the list, people tend to cite each other more and more. That's one inevitable reason of the increase in collaboration in writing papers.

6.5.2. Assumptions

The papers submitted to journals are either accepted or rejected by the journals. In the model it is assumed that *maximum acceptance percentage* is 1. This acceptance percentage provides the acceptance of 64 percent of the papers, that are waiting under peer review in the *paper submitted stock*, each year. This fraction depends on the *reputation* of the faculty. Only the universities that have a *reputation* level of 100 can have the *maximum acceptance fraction. A type papers* are submitted to *A type journals*, *B type papers* are submitted to *B type journals* and *C type papers* are submitted to *C type journals.* This makes it possible to assume that *acceptance fraction* is almost the same for the three paper types.

Reputation adjustment time is assumed to be 5 years.

6.5.3. Description of the Structure

The stock flow diagram of the *reputation* sector is provided in Figure 6.34.

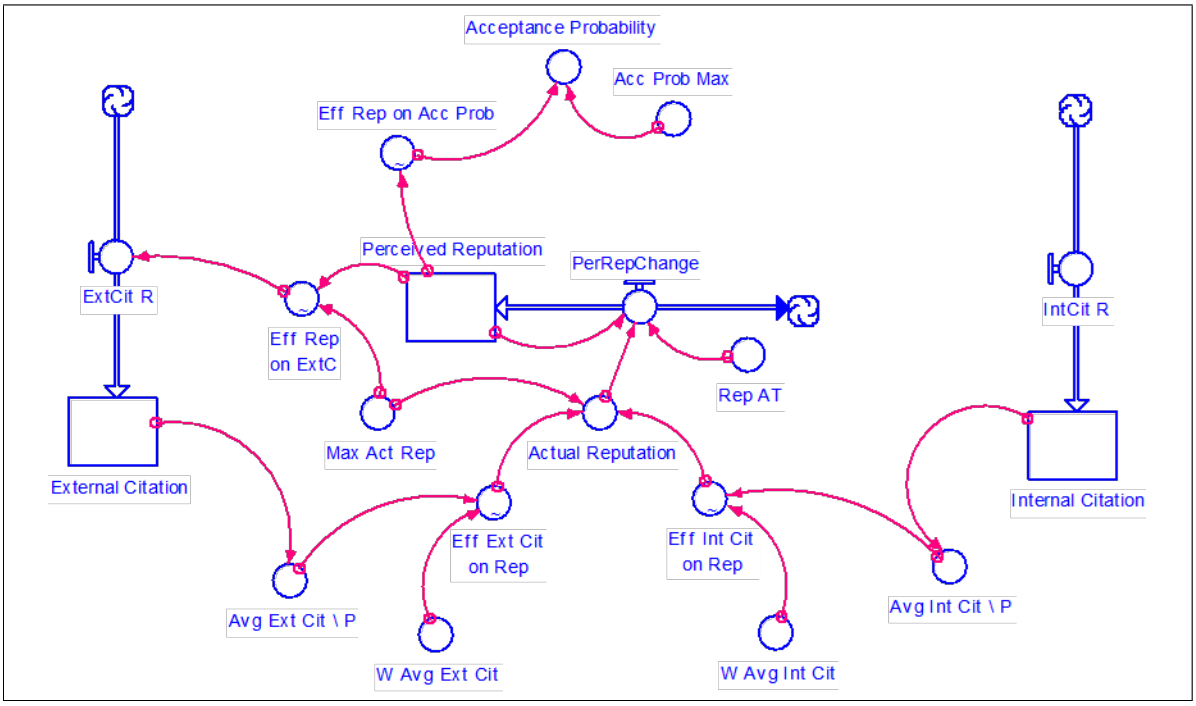

Figure 6.34. Stock flow diagram of the reputation sector

6.5.3.1. Reputation. *Reputation* is modeled with a first order information delay. *Actual reputation* is formed with *effect of external citation on Rep* and *effect of internal citation on Rep*. The *actual reputation* needs some adjustment time to be perceived in the world. *Effect of external citation on Rep* is stronger than the *effect of internal citation on Rep*. The formation of *effect of external citation* and *effect of internal citation on reputation* is similar to formation of citation pressure. *Average external citation per paper* and *average internal citation per paper* values are divided by world averages. The scale of *reputation* is 0-100. *Maximum actual reputation* is 100.

The function *effect of external citation on Reputation* is seen in Figure 6.35. The function *effect of internal citation on Reputation* is seen in Figure 6.36. The effects are summed up in finding *actual reputation* and that sum is multiplied with *maximum actual reputation*. In this effect structure, *external citations* have four times higher power than *internal citations*. The scale of *effect of external citations on reputation* is 0.2-0.8 where the scale of *effect of internal citations on reputation* is 0.05-0.2.

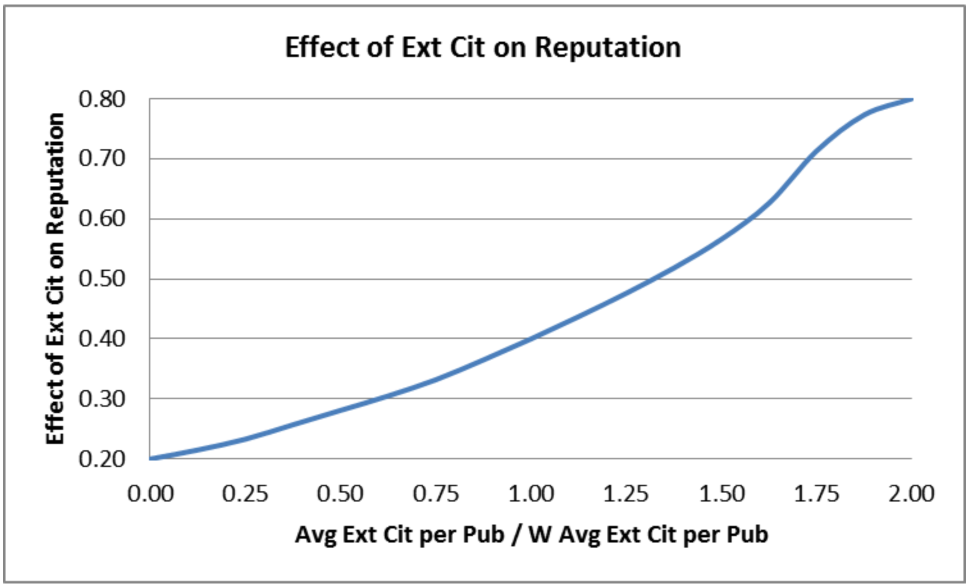

Figure 6.35. Effect of external citation on reputation

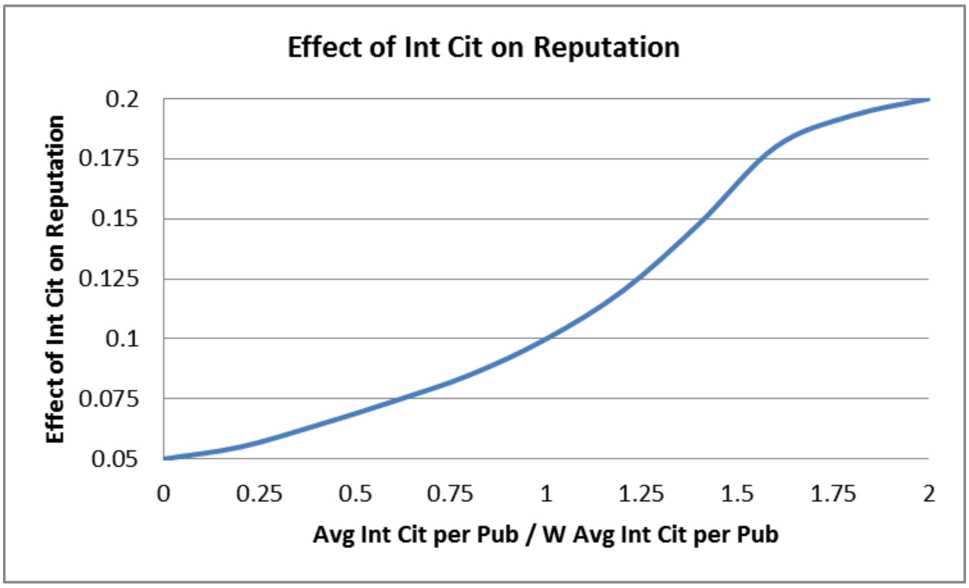

Figure 6.36. Effect of internal citation on reputation

$$ActualReputation = MaxActRep * (EffExtCitonRep + EffIntCitonRep) \tag{6.34}$$

$$PerceivedReputation(t) = PerceivedReputation(t - dt) + \\ + (PerRepChange) * dt \quad (6.35)$$

$$PerceivedReputationChange = \frac{(ActualReputation – PerceivedReputation)}{RepAT} \quad (6.36)$$

Initial *Perceived Reputation* is taken as 40 because *actual reputation* is calculated as “39.91” with the *average external* and *internal citations per publication* value of Bogaziçi University Engineering Faculty.

One of the variables that is affected by *reputation* is *external citation rate*. The effect function is seen in Figure 6.37.

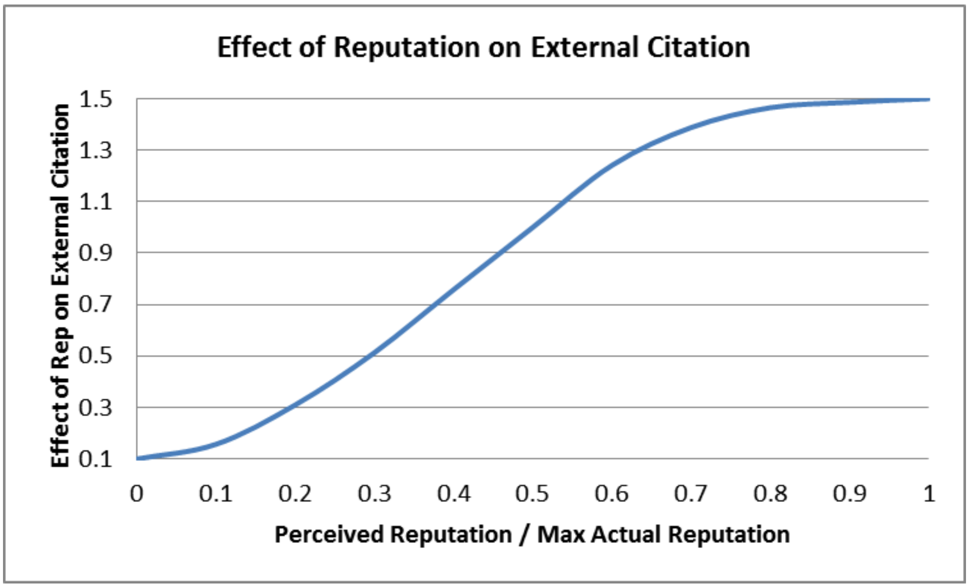

Figure 6.37. Effect of reputation on external citation

The “normal” value of *reputation* is “50”. That means, citations of a university which has a *reputation* of level 50 will not be affected from the *reputation* factor. If *reputation* level is more than 50, number of citations received each year is higher than the normal level. Similarly, if *reputation* level is less than 50, number of citations received each year is less than normal level. The equation of *External Citation rate* is below:

$$\begin{aligned} ExternalCitRate = (PublicationA * ExtCit\backslash P\backslash Y\ A + \\ + PublicationB * ExtCit\backslash P\backslash Y\ B + PublicationC * \\ * ExtCit\backslash P\backslash Y\ C) * \mathit{EffSkillonCit} * \mathit{EffReponExtC} \end{aligned} \quad (6.37)$$

The second variable that is affected by reputation is *Acceptance Fraction. Acceptance Fraction* is described in the following section.

<u>6.5.3.2. Acceptance Fraction.</u> *Acceptance Fraction* is a value between 0.64 and 0.32. The formula is seen below. The effect function is seen in Figure 6.38.

$$\begin{aligned} AcceptancePercentage = AcceptancePercentageMax * \\ * \mathit{EffectofReputationonAcceptancePercentage} \end{aligned} \quad (6.38)$$

$$AcceptanceFraction = AcceptancePercentage / PublishTime \quad (6.39)$$

Acceptance Percentage Max is 1. The corresponding *Acceptance Fraction* values are seen in Figure 6.39.

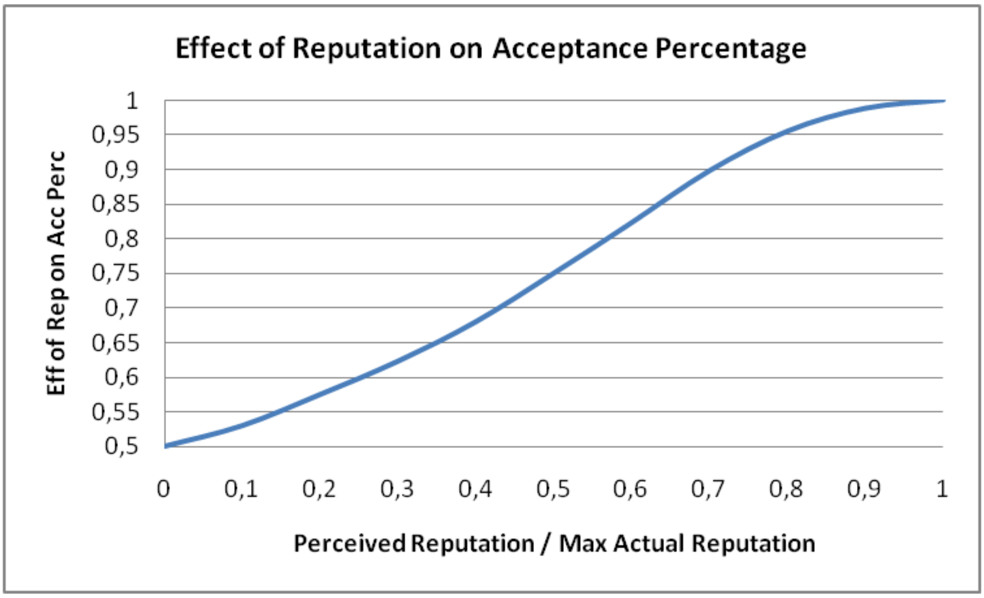

Figure 6.38. Effect of reputation on acceptance fraction

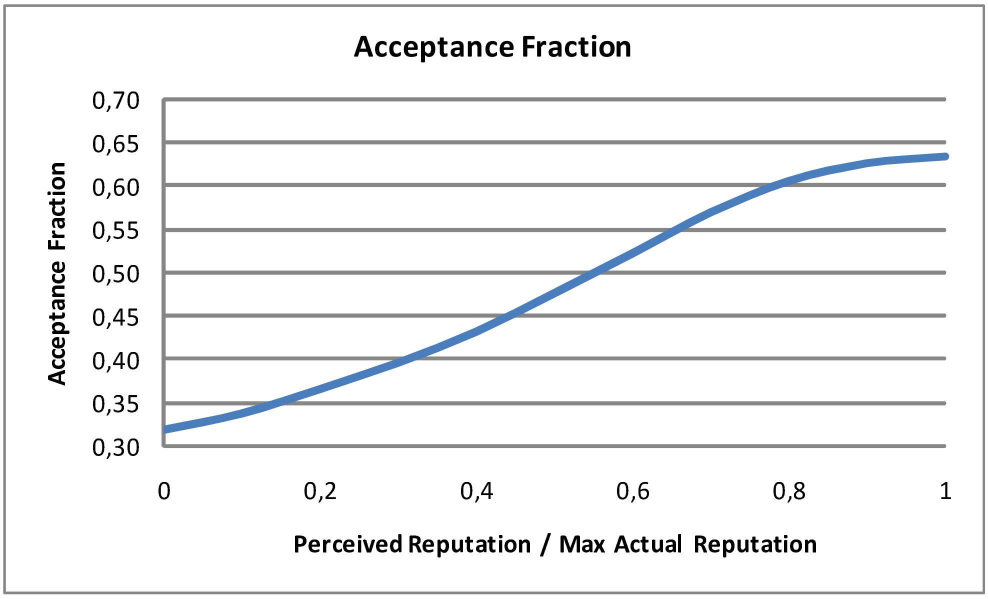

Figure 6.39. Acceptance Fraction

Only if reputation is equal to 100, meaning that the faculty is well known by every other university in the world, acceptance percentage is 1 and acceptance fraction is 0.64. The less the *reputation*, the less the *acceptance fraction*. When *reputation* level equals to 50, *acceptance fraction* is 0.32. In the model, initially *reputation* is 40 and corresponding *acceptance fraction* is 0.43.

6.6. Citation Sector

6.6.1. Background Information

External citations are received from papers written by researchers who are not faculty members. *Internal Citations* are received from papers written by authors of the papers themselves or colleagues of the authors. The rates at which internal and external citations are received are different. That's why *citation/publication/year* parameters are different for *external* and i*nternal citations.*

What we call *internal citations* in this study is widely called "self-citations" in literature. Glanzel et al.(2004) analyzed the role of self citations for understanding basic regularities of self-citations and for being able to set a methodological way for criticizing self citation patterns in empirical studies. They define self citations with the following statement:

> A self citation occurs whenever the set of co-authors of the citing paper and that of the cited one are not disjoint, that is, if these sets share at least one author.

For finding the parameters related to *internal citations*, the findings of Glanzel et al (2004) are employed. Glanzel's definition for self citation and our definition for *internal citation* in this study coincide substantially. The only differing case occurs when a paper written by members of the faculty cites a paper written by other members of the faculty but none of the authors of the citing paper is an author of the cited paper. However this rare case does not interfere with our assumption that the findings about self citations can be used for internal citations.

High quality papers receive high number of citations. That's why *cit/pub/y* parameters are different for *A, B* and *C type publications.*

The number of citations received by the publications are increasing every year. One possible reason is the increase in number of publications in the world. The other possible reason is that, may be researchers tend to give more references in their publications. Whatever the reason is, the *citation/publication/year* parameter has to be multiplied with a trend function to find the correct citation rates. The world trend is calculated by using the real data and the values are shown in Section 6.6.4.

Reputation and *skill* are two important factors affecting the rate of citation receiving.

6.6.2. Assumptions

There are kinds of factors affecting citation-receiving rates but in the model, it is assumed that all of the effects are covered with *reputation* and *skill.*

The parameter *world trend in citations* is assumed to be the same for *A, B* and *C type publications.* The reason is that, it is calculated based on world data. World data gives the most reliable and unbiased value, so we can use that value for any quality type as the grand average.

6.6.3. Description of the Structure

The stock flow diagram of the citation sector is seen in Figure 6.40. As explained before in Section 6.1, only the publications that are in *Publication A/B/C* stocks are citable publications. The citations received by those publications accumulate in two kinds of stocks in the model; *External Citations* and *Internal Citations.*

6.6.3.1. External Citations. *External citations* are given by researchers who are not faculty members. The equations related to *external citations* are seen below.

$$ExternalCitation(t) = ExternalCitation(t - dt) + (ExtCitR) * dt \qquad (6.40)$$

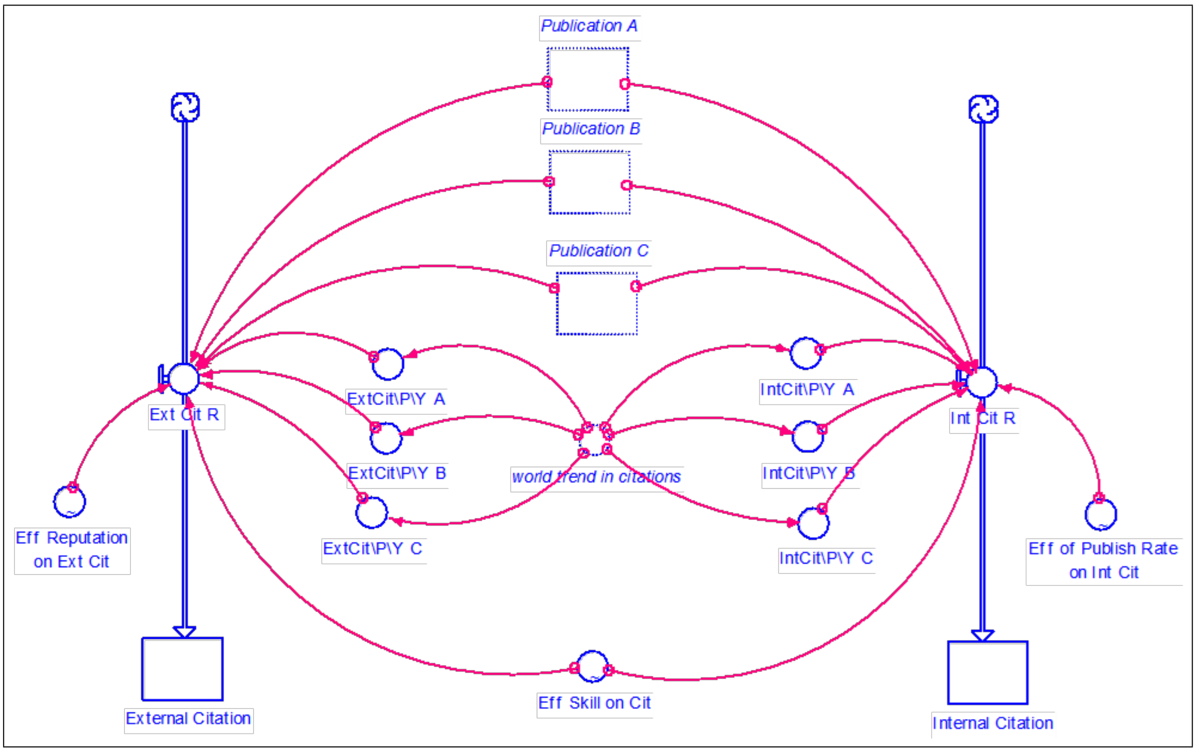

Figure 6.40. Stock flow diagram of the citation sector

$$
\begin{aligned}
ExternalCitRate = (&PublicationA * ExtCit\backslash P\backslash Y\ A + PublicationB * \\
&* ExtCit\backslash P\backslash Y\ B + PublicationC * ExtCit\backslash P\backslash Y\ C) * \\
&* EffSkillonCit * EffReponExtCit
\end{aligned}
\quad (6.41)
$$

Citation per publication per year parameters are related to the citation receiving rates of the *A/B/C type journals* and the publications published in those journals. It is assumed that, the number of citations received in a year by an average *A type publication* that is published in an *A type journal* equals to $Ext\ Cit|P|Y\ A$. The same logic is valid for *B* and *C type publications*.

There are two factors positively effecting external citation receiving rate; reputation and skill.

$Ext\ Cit|P|Y\ A$ is an average value. If the author of the paper in that *A type* *journal* is from a very reputable university, then the number of citations of his papers will be higher than *Ext Cit*$\setminus$*P*$\setminus$*Y A* thanks to the *Eff Rep on Ext Cit* factor in the *external citation receiving rate* formula. In the same manner, if the author of the paper is from a university where *skill* level of the faculty members is very high, the paper would be a good one . The citations received by that paper will be higher than *Ext Cit*$\setminus$*P*$\setminus$*Y A* thanks to the *Eff Skill on Cit* factor in the *external citation receiving rate* formula. Again the same logic is valid in terms *reputation* and *skill* for *B* and *C type publications. Effect of skill on ext cit* is explained in detail in Section 6.4. *Effect of reputation on ext cit* is explained in details in Section 6.5.

The initial values of *Ext Cit*$\setminus$*P*$\setminus$*Y A*, *Ext Cit*$\setminus$*P*$\setminus$*Y B* and *Ext Cit*$\setminus$*P*$\setminus$*Y C* are calculated according to real data of Bogaziçi University engineering faculty. These average numbers are not constant. The numbers are increasing every year. The rate of increase is called "world trend in citations" in the model. The world trend is calculated from the world citation data (6.6.4) The *Ext Cit*$\setminus$*P*$\setminus$*Y A, Ext Cit*$\setminus$*P*$\setminus$*Y B* and *Ext Cit*$\setminus$*P*$\setminus$*Y* parameters are simply multiplied with "world trend in citations" in the *citation receiving rate* formula.

6.6.3.2. Internal Citations. *Internal Citations* are given by the colleagues or the authors of the papers themselves.

The equations related to *internal citations* are seen below.

$$InternalCitation(t) = InternalCitation(t - dt) + (IntCitR) * dt \tag{6.42}$$

$$\begin{aligned} InternalCitRate = (&PublicationA * IntCit\backslash P\backslash Y\ A + PublicationB * \\ &* IntCit\backslash P\backslash Y\ B + PublicationC * IntCit\backslash P\backslash Y\ C) * \\ &* EffSkillonCit * EffofPublishRate \end{aligned} \tag{6.43}$$

Internal citations have a different behavior than *external citations*.

Glanzel (2004) found that, there is nothing arbitrary in self-citations from the statistical viewpoint. They analyzed the publications of year 1992 and citations received by those publications until 2001. They found that the conditional expectation of self-citations for given number of foreign citation could be characterized as a square-root law. They provide an equation for the expected number of self citations given the number of foreign citations. The equation is seen below:

$$f(k) = (k + 0.25)^{0.55} \tag{6.44}$$

where k=number of foreign citations and f(k)= expected number of self citations.

They add, about behavior of self-citations that, in the third after year of publications, the expected number of self-citation for a given number of foreign citations becomes practically stationary. Therefore, the aging structure of *internal citations* is different from aging structure of *external citations*. This fact is not adopted in the simulation model for the sake of simplicity. Rather, the parameter *int cit /p/y* parameter is found to provide the same expected number of *internal citations* but in the whole lifetime of the publication. Table A.7 which is from Glanzel's paper, presents the conditional self citation means for papers published in 1992 with at most 50 foreign citations for 1-year to 10-year citations windows where k is number of foreign citations and $\dot{\mathrm{f}}$(k) is estimated expectation.

There are two functions effecting *internal citation receiving rate*; *skill* and *publish rate*. *Reputation* is not necessary in receiving internal citations.

Skill level of faculty has a positive effect on *internal citations*. Just as in the *external citation* case, it is assumed that if the author of a paper is from a university where *skill* level of the faculty members is very high, the paper would be a good one. Moreover, the previously published papers of those faculty members would be good papers as well with regard to the high *skill* level. The *internal citation* traffic of such a faculty will be heavier. *Eff Skill on Cit* factor in the *internal citation* receiving rate formula provides the increment in *citation receiving rate*.

Publish rate affects the *internal citation receiving rate*. Since *internal citations* are coming from the university in question, how much *internal citations* you get each year is directly related to how much you publish each year. The *effect of Publish Rate on Int Cit* in the model is seen in the Figure 6.41.

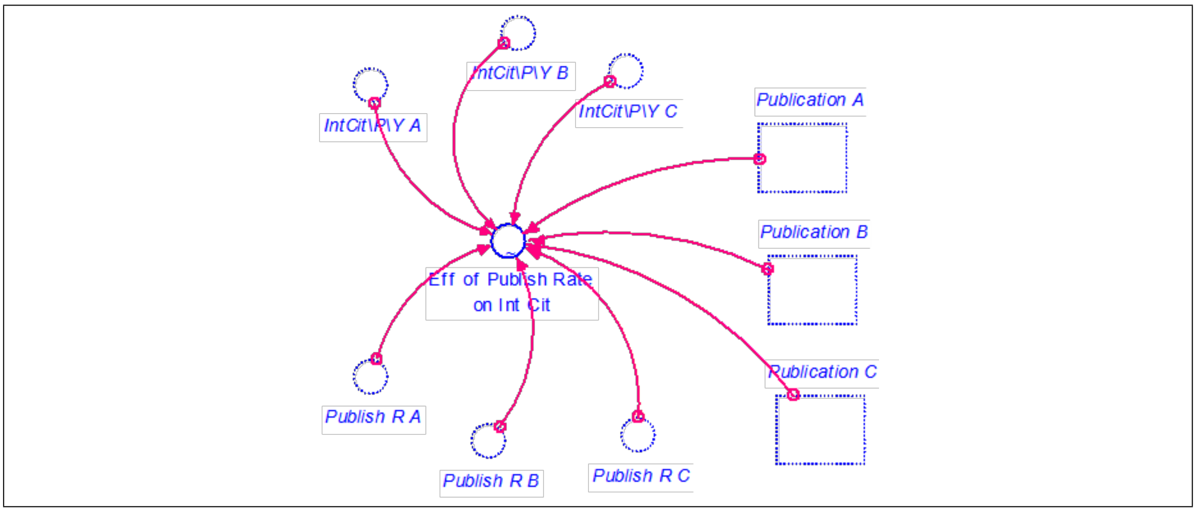

Figure 6.41. Effect of publish rate on internal citations in the model

This effect is included in this structure only for making sure that there is no unreasonable behavior in extreme conditions. This effect formula makes sure that the number of *internal citations* received by a paper can at most be 10. The publish rates can increase enormously, but *internal citations* have an upper limit for each paper. In the data analysis part this upper limit is explained in detail.

The *effect of publish rate on internal citations* function is seen in Figure 6.42.

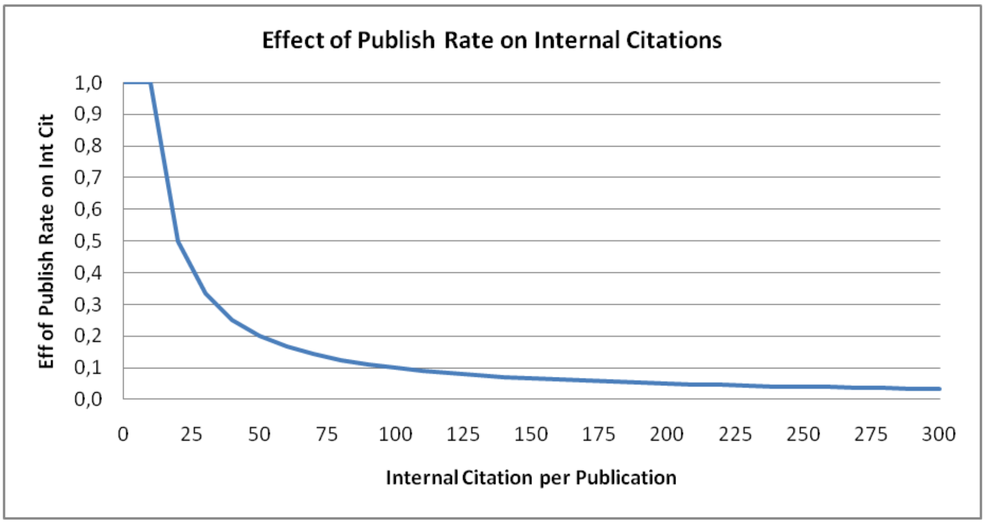

Figure 6.42. Effect of publish rate on internal citations

6.6.4. Parameter Estimation

A simplified paper-citation model is used for finding initial stock values of *internal* and *external citations* and *ext cit /p/y A/B/C* and *int cit /p/y A/B/C* parameters.

The *publication* stocks have been initialized and run as explained in Section 6.1. Firstly, without distinguishing citations into external and internal categories, the parameter *citation/publication /year* is found with the same method applied in Section 6.1.4.1.

Number of publications of each type is given to the model year by year (one year at a time). *Cit|P|Y A* parameter is found by trial and error such that it gives the required number of citations in the life time of the *A type publications*. The same procedure is repeated with *B* and *C type publications* for each year for finding the *cit/p/y B* and *cit/p/y C*. Then, the model is run once more from year 1981 to 2006 with each year's *publish rates* and with giving the *Cit|P|Y A, Cit|P|Y B, Cit|P|Y* parameters of each year to the model. The number of citations accumulated in the citation stock in year 1995 is taken as the initial value of sum of citation stocks in the main model.

The number of citations found with this procedure is "596". *cit/p/y* parameter of each publication type is provided in Table A.5.

In the main model, we need *int cit /p/y* and *ext cit /p/y* for each publication type of year 1995, which is the initial year. In 1995, 9 *A type publications*, 39 *B type publications* and 60 *C type publications* were published. The number of citations those publications received up to 2009 are 489, 447 and 117 respectively. Average number of citations of an A type publication is 54, that of a *B type publication* is 11.5 and that of a *C type publication* is 2. According to Glanzel's table which can be seen in Table A.7, 8 of the 54 citations of *A type publications* are of class internal, 3.4 of the 11.5 citations of *B type publications* are of class internal and 1 of the 2 citations of *C type publications* are of class internal. The values presented here are included in Table A.6.

By giving the number of *A, B and C type publications* of year 1995 as *publish rate* with a pulse function to the simplified publication-citation model, the *ext cit/p/y* and *int cit /p/y* parameter values are found such that they provide the mentioned *external* and *internal citations*. For year 1995, the calculated parameter values are seen in the Table 6.7.

Table 6.7. Ext cit /p/y and Int cit /p/y parameters for year 1995

	Type A	**Type B**	**Type C**
int cit / p / y	0.49	0.21	0.06
ext cit / p / y	5.45	1.00	0.12

With the *int cit /p/y* parameter, the *internal citations* are accumulated in *internal citations* stock. The number of *internal citations* is 96 in year 1995. This number is subtracted from previously calculated number of total citations which is 596 and number of *external citations* in year 1995 is found as 500. These two numbers are carried to the main simulation model as the initial values of the *internal* and *external citation* stocks.

Int cit /p/y and *ext cit /p/y* parameters are multiplied with “world trend in citations” for calculating the future values of the parameters.

World trend in citations is found simply by dividing the *cit/p/y* parameter for each year with the *cit/p/y* parameter of year 1995. The trend can be observed in the Figure 6.43.

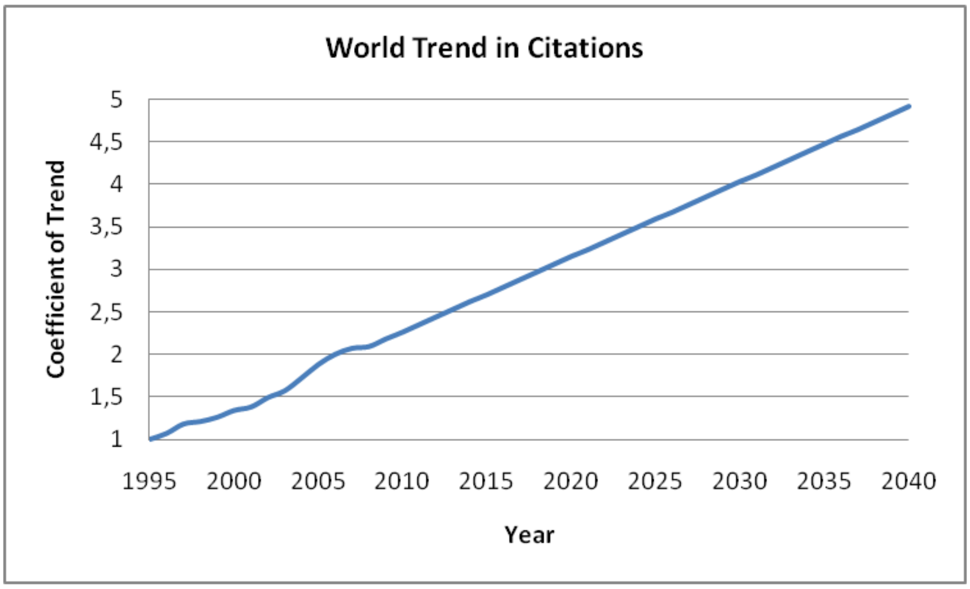

Figure 6.43. Coefficient of trend in the world citations to be multiplied with initial cit/pub/y parameters

7. ANALYSIS AND VALIDATION OF THE MODEL

Stella 9.0.2 software is used for running the simulation model. Time unit is years. Length of simulation is forty-five years, from 1995 to 2040. Time step is 1/8 in the simulation. The integration method chosen in running the model is Euler's Method.

In this chapter, first the base behavior of the model will be analyzed. Then, in the validation section, the experiments conducted in order to test the validity of the model will be summarized. The compatibility of model behavior with the real life behavior of Bogaziçi University Engineering Faculty will be presented.

7.1. Analysis of the Base Behavior

Initially in the model, the *avg cit/pub* value is 2.84 where *world avg cit/pub* is 4.38. *avg pub/f/y* value is 0.28 where *world avg pub/f/y* is 1.57. There is pressure on researchers in terms of both publications and citations. The most significant response of researchers to this fact is the increase in *research time* in a very short time. We see that in year 2006, *research time* increases more than two times and reaches a level of 0.46 year per faculty per year, where it was only 0.2 year per faculty per year in 1995. The increase continues until 2012. Between 2012 and 2016, *research time* stays steady at level 0.49, which is the highest level of *research time* ever. Starting in year 2016, *research time* decreases slightly and slowly. Change in the attitude of researchers towards *research time* originates from the publication pressure on them (Figure 7.1).

With the increasing *research time* levels, *publish rates* increase. The behavior is seen in Figure 7.2. From 1995 to 2006, where the pressures are very strong, the *publish rates* of all three quality classes of publications increase. *Publish rate B* and *C* increase more than *publish rate A*. This is understandable because *A type publications* require more *research time* and as we see in Figure 7.4, *fraction of research time allocated to A research* is not as much as *research time allocated to B* and *C research. Publish rate B* and *publish rate C* continue increasing until the end of the simulation period. However, *A type publications* reach the highest level in year 2014 with 19 *A type publications*, and then decrease and stabilize. This is due to the lack of pressures, which motivate researchers to make more *A type publications* (Figure 7.2).

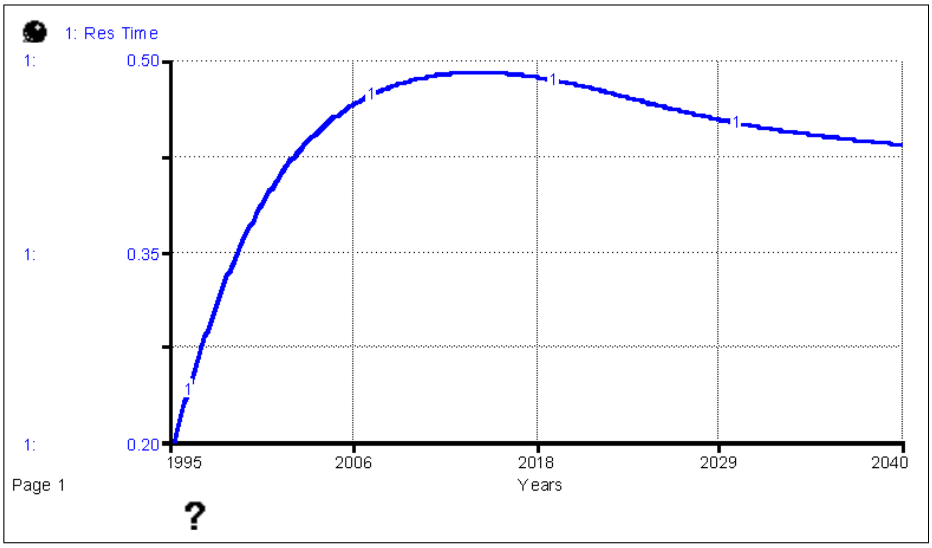

Figure 7.1. Research time in the base run

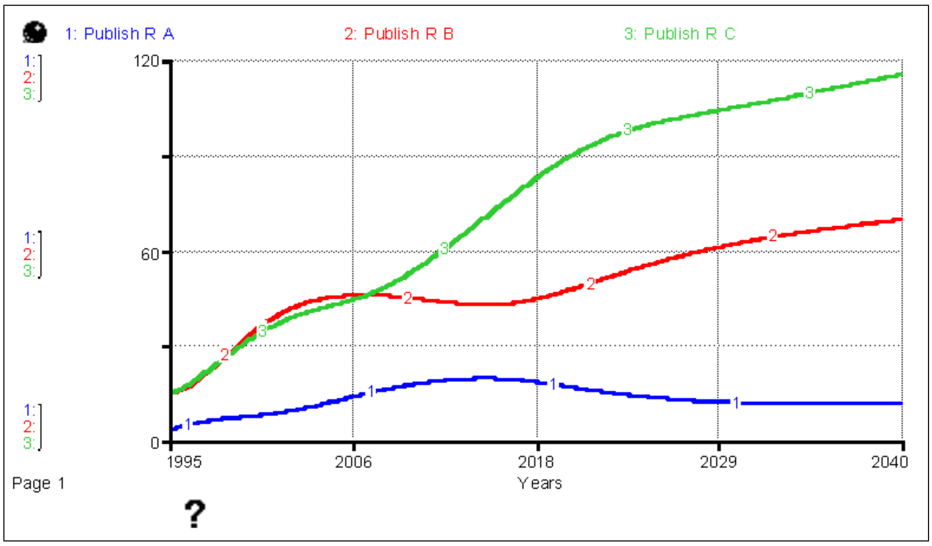

Figure 7.2. Publish rates in the base run

The rapid increase in *publish rates* in the first years ends up with a rapid increase in *avg pub/f/y*. As the parameter increases, the corresponding pressure decreases. We see the effect of decrease in publication pressure on research time in Figure 7.1after year 2016 as a decrease in *research time*. The decrease in *research time* slows down the increase in *avg pub/f/y*. The parameter almost stabilizes at 1.18 at the end. It should be mentioned once more that world *avg pub/f/y* is 1.57. The publications get very far from beginning to the end of simulation period where ultimate goal is to reach the world average (Figure 7.3).

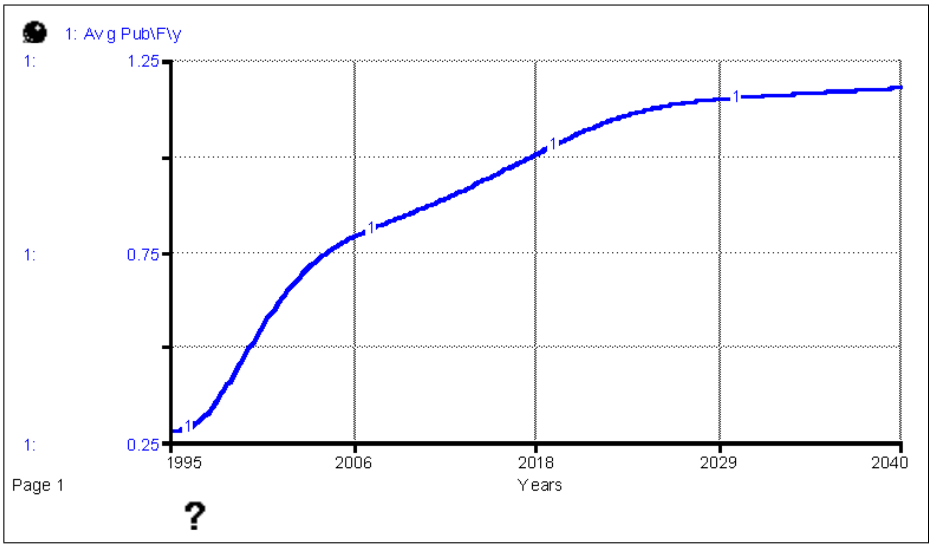

Figure 7.3. Average publication per faculty per year in the base run

The fractions of research time allocated to A, B and C research are seen in Figure 7.4. Initially *fract of Res T for A* is 0.29, *fract of Res T for B* is 0.47 and *fract of Res T for C* is 0.24. The ending values are 0.15, 0.46 and 0.38 respectively.

fract of Res T for A oscillates around 0.29 at the beginning. From 2009 to 2012, it is at its maximum level. The faculty catches the world average in terms of citation per publication in year 2015. After 2012, with the decreasing citation pressure, the motivation for A type research decreases and this fact ends up with a stabilization of *fract of Res T for A* in a low level.

fract of Res T for B oscillates around 0.45 and stabilizes at 0.46 at the end. The pressures are easing off and this allows making B type publications.

fract of Res T for C is at the lowest level in the beginning. It increases due to publication pressure. However, the increase is not very dramatic because although publication pressure exists all the time, its strength keeps decreasing in the entire simulation period (Figure 7.4).

Figure 7.4. Research time allocation in the base run

In the citation site, the situation is better off. *Avg cit/pub* value of the faculty catches the world average in year 2015. From then on, citation pressure decreases. The decrease in citation pressure results in lower *fract of Res T for A* but high citation receiving rates continue because of both plenty of previously published *A type publications* and continuing high *publish rate B*. The satisfactorily increasing *external* and *internal citation receiving rates* are seen in Figure 7.5.

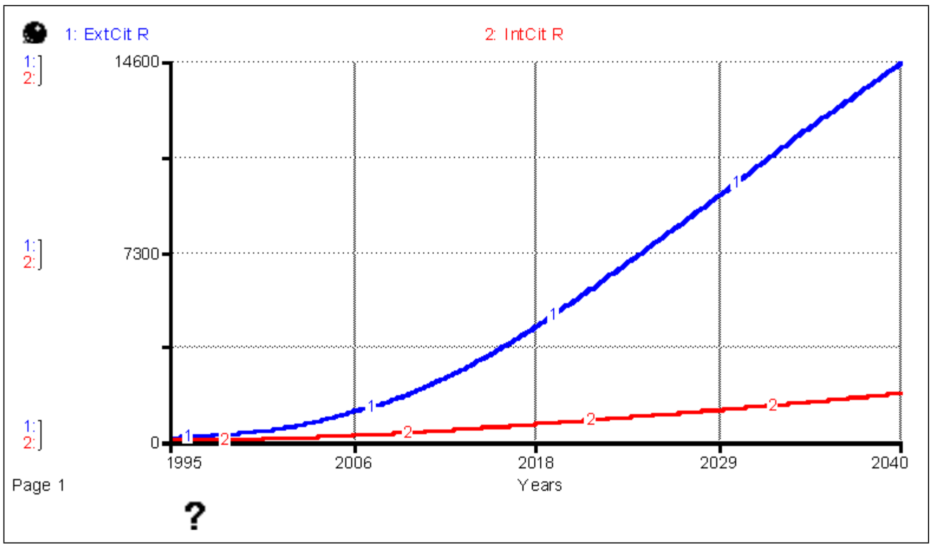

Figure 7.5. Citation rates in the base run

Avg cit/pub catches world average very soon as mentioned above. However, *external* and *internal citations* should be analyzed separately because the situation is not the same for them. There is a sustained increase in *avg ext cit / pub*. After 2007, the slope of increase increases and the increased slope continues ever. This provides a much higher *avg ext cit / pub* than world average at the end. On the other hand *avg int cit / pub* can never reach world average but the difference between them decreases consistently during the simulation. At the end, *avg int cit / pub* is 5.15 where world average is 5.25. The values of *avg cit/pub* parameters are seen in Figure 7.6.

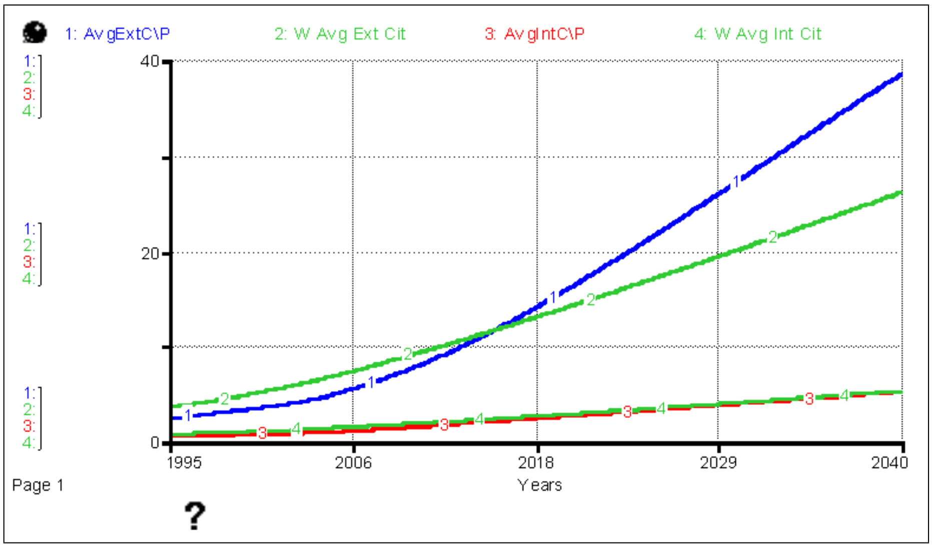

Figure 7.6. Citation per publication in the base run

Reputation increases during the simulation period. Initially *reputation* of faculty is at level 40 out of 100. From the beginning to 2006, increase in *reputation* is very slight. Starting in 2007, by coming closer to the *world average cit/pub*, increase in *reputation* accelerates. The increase in *reputation* makes a saturating behavior and reaches level 63 at the end of the simulation.

Acceptance fraction has a base level and its increase directly depends on *reputation* changes. With the increasing *reputation*, *acceptance fraction* reaches level 0.54 where it starts at level 0.43 in the beginning. The shape of its behavior is very similar to that of *reputation*, which is expected (Figure 7.7).

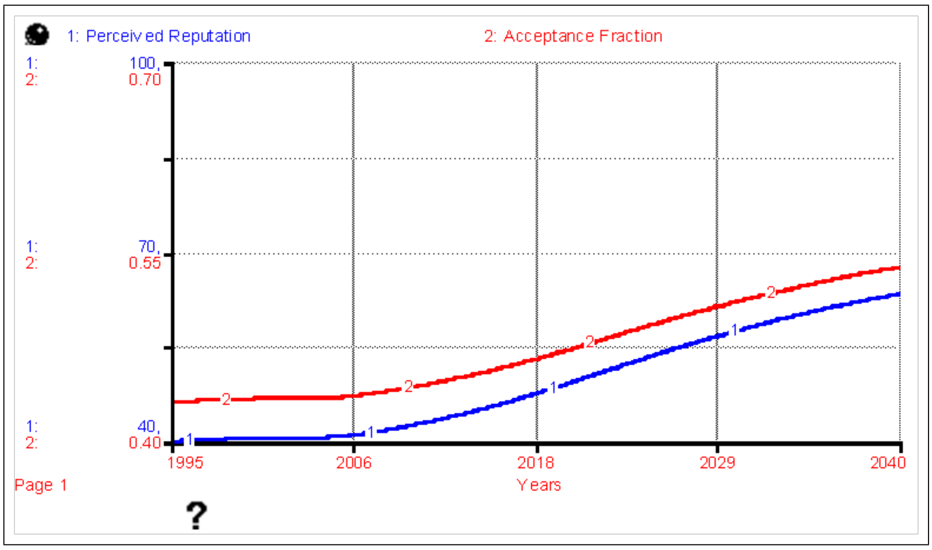

Figure 7.7. Reputation and acceptance fraction in the base run

The base run is actually one of the scenarios that can be drawn by using the model in hand. What makes it presented in this section as the base behavior of the model but not a scenario is that, the behavior exhibited by the model herein depends solely on our base assumptions. Base behavior obtained from model for the first 11 years is completely compatible with the real behavior of Bogaziçi University engineering faculty as will be explained in Section 7.2. Considering this fact, we trust in our base assumptions. The assumptions that are employed in the first years of simulation continue being on stage for the rest of the simulation. Therefore, for the base run we can conclude that, if the mental models of faculty members which produce both the assumptions underlying in the model and results obtained with it does not change, in the long run, the faculty will be in the position presented. In terms of citations, the faculty will be in a very good place with much higher *average citation per publication* values than world averages. In terms of publication productivity, faculty will be in a much better place as well, but it will not be possible to reach the *world average publication per faculty per year* value. Faculty members will spend about 44 percent of their time in research activities and these research activities will be dedicated mostly to medium quality, *B type research*. *A type research* will not be appreciated that much because of the fact that publication pressure will overcome citation pressure. *C type research* will be performed to be able to increase the *average number of publication* *per faculty per year* because of publication pressure. The faculty will be more visible in the academia with increased *reputation* level. It can be concluded that, the faculty will be doing well if our base assumptions about real world are correct.

7.2. Validation of the Model

The purpose of model validation is to assure that the model is an acceptable description of the real system behavior with respect to the dynamic problem (Barlas, 1996). Model validation is carried out in two steps.

7.2.1. Structure Validity

Structure test is to check whether the structure of a model is a meaningful description of the real relations that exists in the problem or not. There are two types of structure tests: direct structure tests and structure-oriented behavior tests (Barlas, 1996).

Direct structure tests assess the validity of the model structure, by direct comparison with knowledge about real system structure. Parameter and variable confirmation, dimensional consistency and extreme condition tests are included in direct structure testing (Barlas, 1996). In the model, all parameters and variables have real life counterparts. The equations and logical relationships are compatible with our knowledge about real system. There is no dimensional inconsistency in equations. Dimensions of the variables and parameters are presented in Table 5.1. All the model equations are valid under extreme conditions.

One of the tests in indirect structure testing is extreme-condition test via simulation. Extreme values are assigned to selected parameters and model-generated behavior is compared to the observed (or anticipated) behavior of the real system under the same extreme condition (Barlas, 1996). Some extreme conditions are simulated.

7.2.1.1. Extreme Condition tests. Extreme condition tests with some key variables are carried out in this section.

Extreme Condition 1: Skill level is very high: Skill level is set to 100. *Publish rates* increase because it is very easy for researchers to write papers with a top *skill* level. *Avg pub/f/y* reaches a very high value. Publication pressure does not exist any more. *Avg cit/pub* reaches very high levels as well which removes citation pressure. In the lack of pressures, researchers are not motivated to make *A type* or *C type* research but they tend to make *B type* research. *Reputation* becomes 99.8 which is acceptable since everybody would know very well a faculty of 100 percent skilled faculty members. Since it is easy to publish for researchers, they do not need to devote so much time in making research. Researchers are already perfect, and they only spend 28 percent of their time on research activities. *Reputation* is seen in Figure7.8. Other related figures are provided in Appendix B (B.1, B.2, B.3).

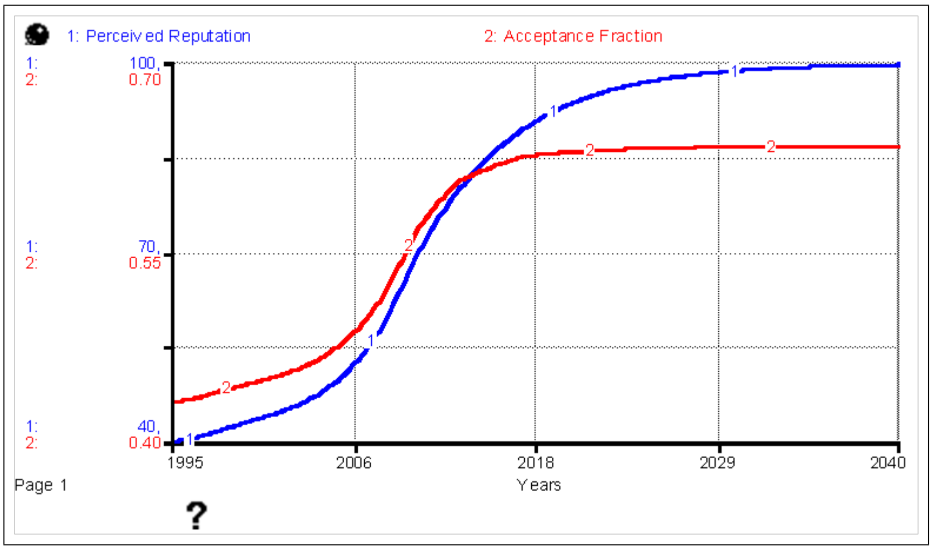

Figure 7.8. Reputation and Acceptance Fraction in Extreme condition 1 – perfect faculty members

Extreme Condition 2: Skill level is very low: Skill level is set to five. *Avg pub/f/y* and *avg cit / pub* are very low. There are strong publication pressure and citation pressure. When both of them are very strong, *A type* and *C type research* becomes hard to do but researchers concentrate on *B type research* to balance both publication productivity and quality. *Research time* increases and reaches 57 percent of faculty's time. Thanks to increased *research time* and increasing number of faculty members, *publish rates* continue increasing, but very slightly. *Reputation* decreases to 3. *Research Time* is seen in Figure7.9. Other related figures are provided in Appendix B(B.4, B.5, B.6).

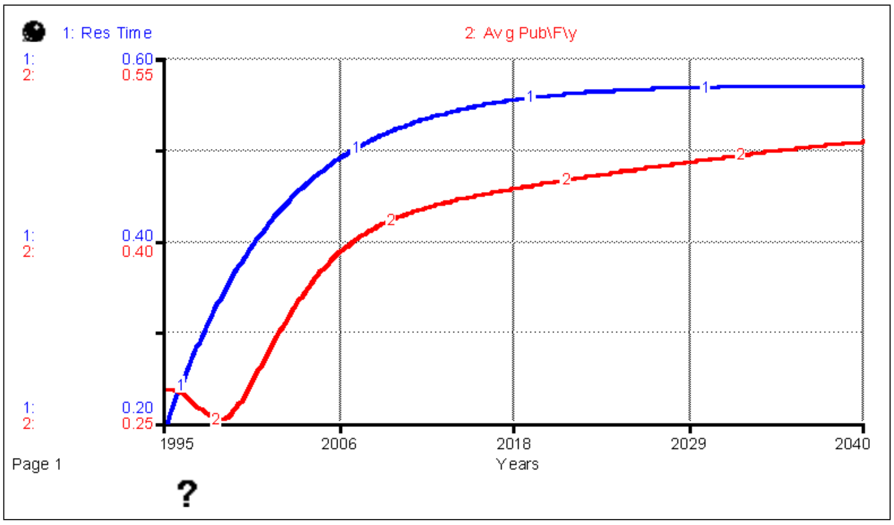

Figure 7.9. Avg pub/f/y and Research Time in Extreme condition 2 – Skill level is very low

Extreme Condition 3: Number of faculty is set to 1: When there is only one faculty member, *publish rates* become almost zero. The *publication* stock levels decrease as expected. The *publish rates* are seen in Figure 7.10.

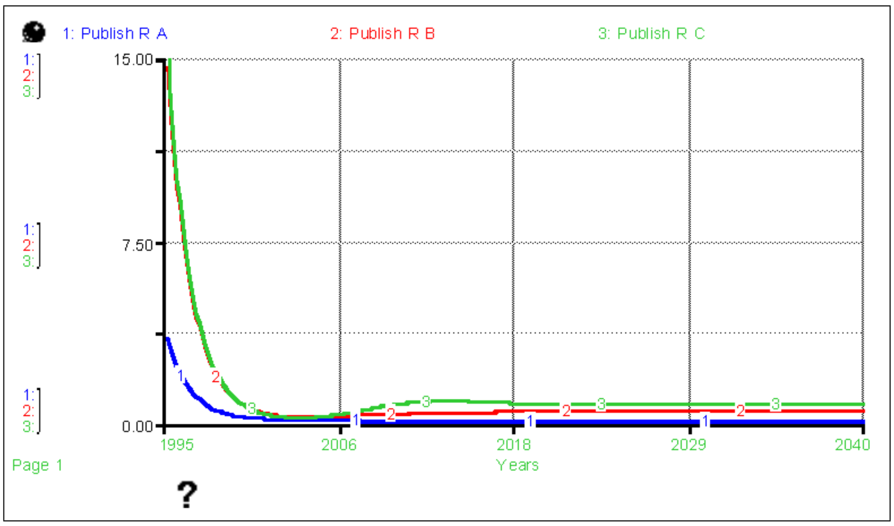

Figure 7.10. Publish Rates in Extreme Condition 3 - # of Faculty is set 1

Extreme Condition 4: Number of faculty is set to 1000: When number of faculty is set to 1000, *publish rates* increase substantially. Accordingly, the publication and citation performance parameters change in expected direction. The *publish rates* are seen in Figure7.11.

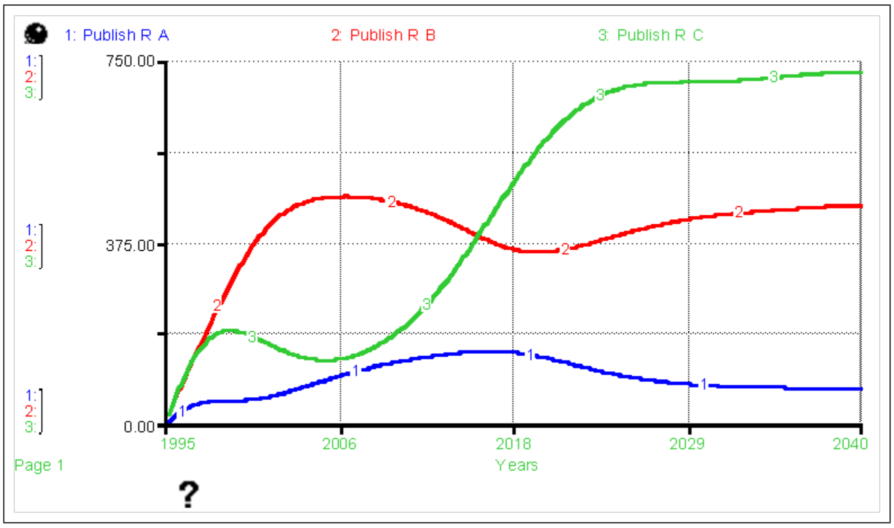

Figure 7.11. Publish Rates in Extreme Condition 4 - # of Faculty is set 1000

Extreme Condition 5: Normal fract A is set to 100: Setting *normal fract A* to 100 and *normal fract C* to 0 means giving an end to *C type research*. *Fract of research time for C* decreases to 0 and *publish rate C* diminishes as expected. However, *fract of research time for A* does not become higher than *fract of research time for B* because *pub/f/y* is at very low levels, causing publication pressure. The final *fract of research time for B* is 62 percent where the final *fract of research time for A* is 38 percent. By making only good quality papers, *avg cit/pub* values increase and this provides a *reputation* level of 95 for the faculty. *Research time* is still very high because of high publication pressure. Research Time allocation is seen in Figure 7.12. Other related figures are provided in Appendix B (B.7,B.8, B.9).

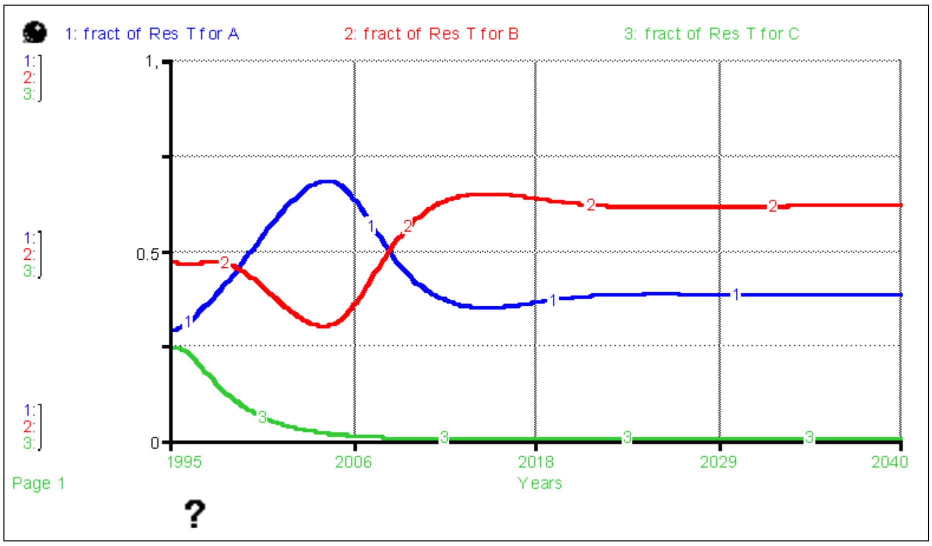

Figure 7.12. Research Time allocation in Extreme Condition 5 - Normal fract A is set 100

Extreme Condition 6: Normal fract C is set to 100: Setting *normal fract C* to 100 and *normal fract A* to 0 means giving an end to *A type research*. *Publish rate A* converges to 0. *Citation rates* decrease dramatically. Citation pressure becomes very strong. This prevents *fract of Res time for C* from being higher than *fract of Res time for B*. Research Time allocation is seen in Figure 7.13. Other related figures are provided in Appendix B (B.10, B.11).

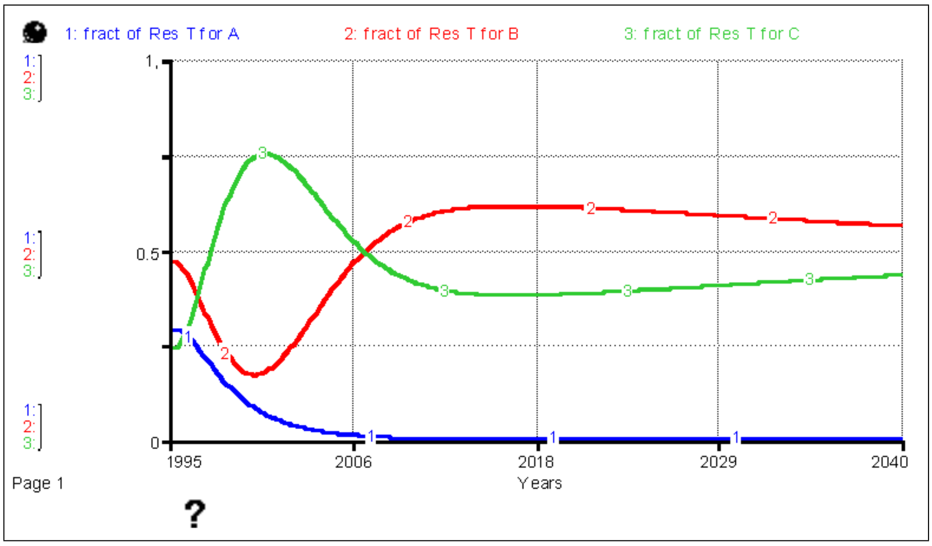

Figure 7.13. Research Time allocation in Extreme Condition 6 - Normal fract C is set 100

Extreme Condition 7: Research Time is set to 0.01: Publish Rates decrease to almost 0. There exists a little *publish rate C*. *Avg pub/f/y* becomes 0.03. Citation pressure is not as much as publication pressure so most of the *research time* is allocated to *C type research*. *Publish rates* are seen in Figure 7.14. Other related figures are provided in Appendix B (B.12).

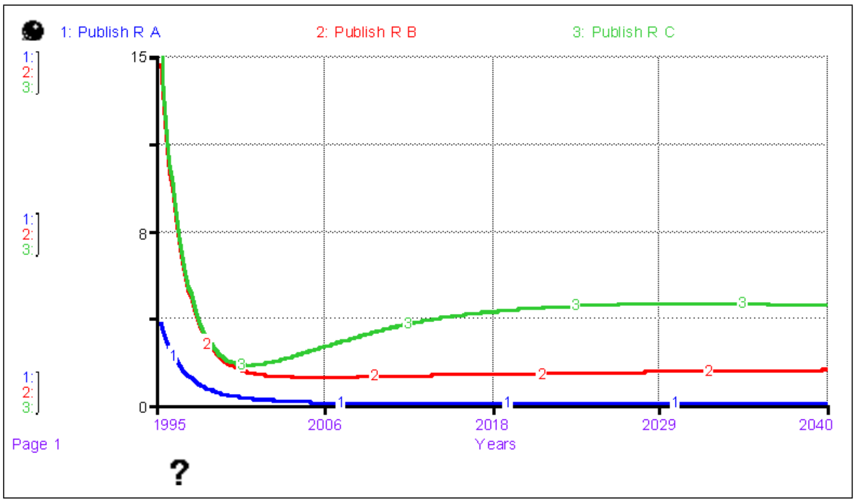

Figure 7.14. Publish Rates in Extreme Condition 7 – Research Time is set 0.01

Extreme Condition 8: Initial Reputation is 0: The model recovers the *reputation* level of faculty in a short time. At the beginning, *citation rates* are low as expected, but in time faculty reach the normal level of *reputation* and *citation receiving rates.* Change in reputation is seen in Figure 7.15.

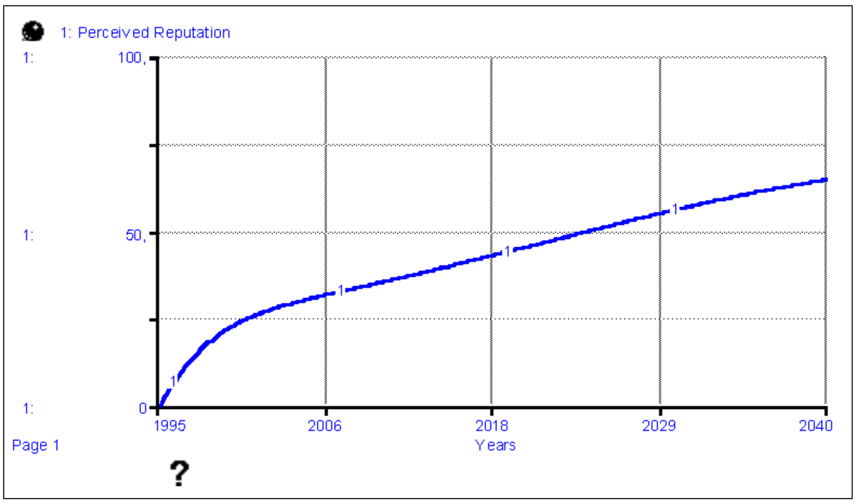

Figure 7.15. Reputation in Extreme Condition 8 – Initial Reputation is set 0

Extreme Condition 9: Initial Reputation is 100: Reputation does not stay in that high level so long, the model recovers the *reputation* level in a short time. *Avg cit /pub* value reaches the world average in a very short time because of high *citation receiving rate* at the beginning. The expected results are obtained in terms of other parameters. Related figures are provided in Appendix B (B.14).

Extreme Condition 10: Acceptance Fraction is set to 0.01: Faculty cannot publish what they write. They tend to write *C type publications* because of the very strong publication pressure on them. As a result, *paper writing rates* increase very much where *publish rates* are very low. Papers accumulate in *Paper Submitted* Stocks and *reject rates* increase a lot. *Paper Writing rates* are seen in Figure 7.16. Other related figures are provided in Appendix B (B.15, B.16, B.17).

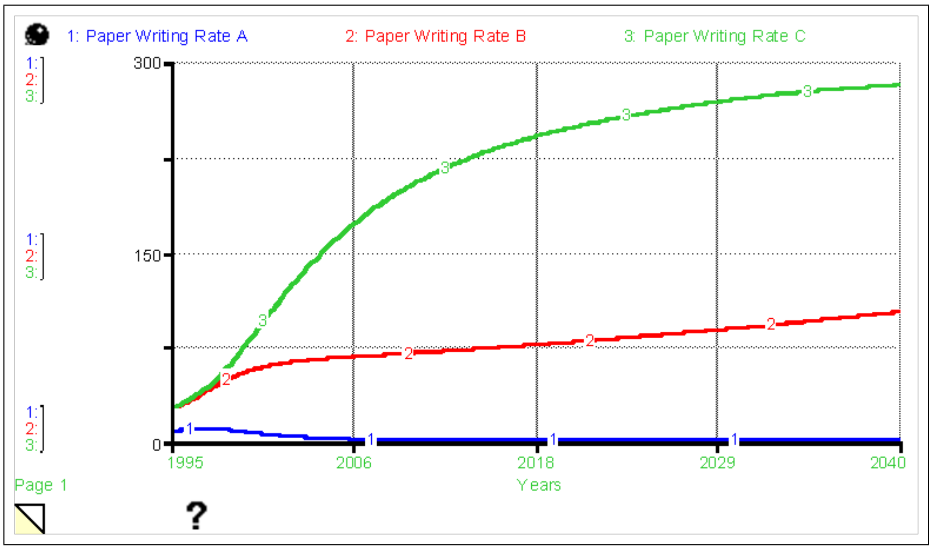

Figure 7.16. Paper-Writing Rates in Extreme Condition 10 – Acceptance Fraction is set 0.01

7.2.1.2. Sensitivity Analysis. Behavior sensitivity test consists of determining those parameters to which the model is highly sensitive, and asking if the real system would exhibit similar high sensitivity to the corresponding parameters (Barlas, 1996). Most of the parameters are tested to find out if there are such parameters that the model is highly sensitive. For that purpose, *Required time A/B/C, Publish Time, Ext cit per pub per year A/B/C, Int cit per pub per year A/B/C, various adjustment time* *parameters* and *normal fract A* and *normal fract B* are tested. The tests verified that the model is valid in terms of those parameters. Some of the results of the sensitivity tests are briefly given in the following sections.

Sensitivity Analysis on Acceptance Fraction: When *Acceptance Percentage Max* is changed, *Acceptance Fraction* is changed accordingly. In the base run, we assume that *Acceptance Percentage Max* is “1”. The values “0.9”, “0.8” and “0.7” as *Acceptance Percentage Max* are tested respectively in Sens Exp 1, 2 and 3. Finally, a different case where *Acceptance Percentage Max* changes from 0.7 to 1 gradually is tested (Sens Exp 4). The corresponding final values of some important variables in the model are shown in Table 7.1.

Sensitivity Analysis on Required Time A/B/C : In the base run, the *required time* for writing an *A type Paper* is 0.8 year/paper, for a *B type paper* it is 0.4 year/paper and for a *C type paper* it is 0.2 year/paper. In sensitivity experiment 1, the required times to write the three types of papers are more different than each other. In Sensitivity experiment 2, the required times are much more different than each other. In sensitivity experiment 3, the values are closer. In the sensitivity experiment 4, all of the three values are higher than base run values. And in sensitivity experiment 5, all of the values are lower than the base run values. The corresponding final values of some important variables are shown in Table 7.2.

The values of research time allocation with sensitivity experiment 2 are seen in Figure 7.17. With the very low *required time C* value, publication pressure decreases and most of the *research time* can be devoted to *A type research.*

The values of research time allocation with sensitivity experiment 3 are seen in Figure 7.18. The *required times* are close to each other. They are neither very low nor very high but they are all close to the *required time B* in the base run. In this case, citation pressure decreases, and publication pressure is high.

Table 7.1. Final Values of Key Variables in Sensitivity Experiments with Parameter *Acceptance Percentage Max*

	Base	**Sens Exp 1**	**Sens Exp 2**	**Sens Exp 3**	**Sens Exp 4**
Acceptance Percentage Max (Sensitivity Parameter)	**1**	**0.9**	**0.8**	**0.7**	**0.7->1**
Acceptance Fraction (start->end)	0.43->0.54	0.38->0.47	0.35->0.41	0.30->0.35	0.30->0.51
Fraction of Research Time (fA-fB-fC)	0.15-0.46-0.39	0.15-0.45-0.40	0.15-0.43-0.42	0.15-42-0.43	0.16-0.46-0.38
Research Time	0.43	0.46	0.48	0.50	0.45
Avg Pub / F / y	1.18	1.10	1.01	0.92	1.15
Publish Rate (A+B+C= Total Pub R)	11+70+116=197	10+62+111=183	9+55+105=169	9+47+97=153	12+67+113=192
Avg Ext Cit / Pub	39	37	35	32	35
Avg Int Cit / Pub	5	5	5	5	5
Reputation	63	60	58	55	57
Paper Submitted A	21	22	23	25	24
Paper Submitted B	130	132	134	135	132
Paper Submitted C	215	235	256	277	222

Table 7.2. Final Values of Key Variables in Sensitivity Experiments with Paramet*er required time* $A/B/C$

	Base	**Sens Exp 1**	**Sens Exp 2**	**Sens Exp 3**	**Sens Exp 4**	**Sens Exp 5**
required time (A-B-C) (Sensitivity Parameter)	**0.8-0.4-0.2**	**1-0.4-0.1**	**2-0.5-0.05**	**0.6-0.4-0.3**	**1-0.8-0.6**	**0.4-0.2-0.1**
Fraction of Research Time (fA-fB-fC)	0.15-0.46-0.39	0.25-0.44-0.31	0.49-0.34-0.16	0.14-0.45-0.41	0.10-0.40-0.50	0.16-0.55-0.29
Research Time	0.43	0.40	0.42	0.44	0.55	0.28
Avg Pub / F / y	1.18	1.32	1.23	1.15	0.65	1.65
Publish Rate (A+B+C= Total Pub R)	11+70+116=197	13+53+153=219	12+42+152=206	16+79+97=192	7+37+63=107	18+125+132=275
Avg Ext Cit / Pub	39	29	17	50	37	55
Avg Int Cit / Pub	5	5	4	6	5	6

Figure 7.17. Research Time Allocation in sensitivity experiment with required time values in experiment 2

Figure 7.18. Research Time Allocation in sensitivity experiment with required time values in experiment 3

7.2.2. Behavior Validity

Once enough confidence has been built in the validity of the model structure via structure validity tests, one can start applying certain tests designed to measure how accurately the model can reproduce the major behavior patterns exhibited by the real system. It is crucial to note that the emphasis is on pattern prediction (periods, frequencies, trends, phase lags, amplitudes ...), rather than point (event) prediction in behavior validity testing (Barlas, 1996).

By using the real data, behaviors generated in the model and real behaviors of faculty are compared for the first eleven years. The model generates almost the same behaviors as the real life behaviors. The future behavior is found to be consistent with our assumptions in all aspects. Real behavior of the system versus model results for the tested parameters are presented in the following subsections.

<u>7.2.2.1. Total Publish Rate.</u> *Total publish rate* is the sum of *Publish Rate A, Publish Rate B* and *Publish Rate C* (Figure 7.19). Real data and model results are compatible.

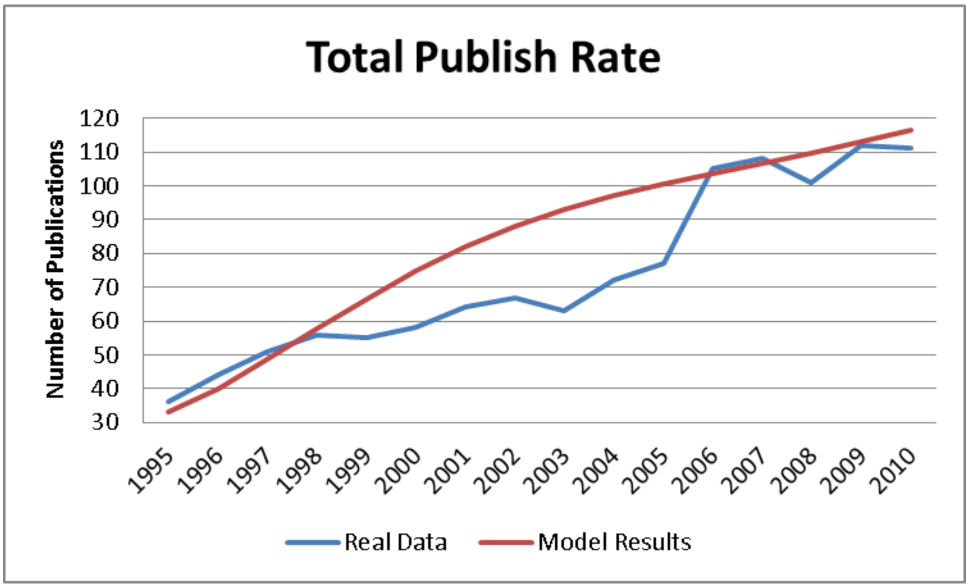

Figure 7.19. Total publish rate

<u>7.2.2.2. Publish Rates with quality classification.</u> Real publish rate versus model *publish rate* for each class of publications are provided in the following figures. *Publish rate A* is seen in Figure 7.20. *Publish rate B* is seen in Figure 7.21. *Publish rate C* is seen in Figure 7.22. Reproduced publish rates with model are compatible with real publication performances.

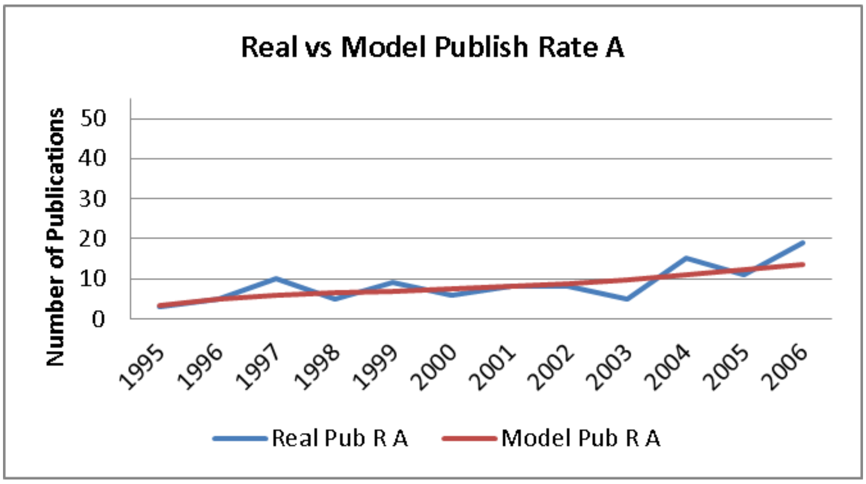

Figure 7.20. Real publish rate vs model publish rate A

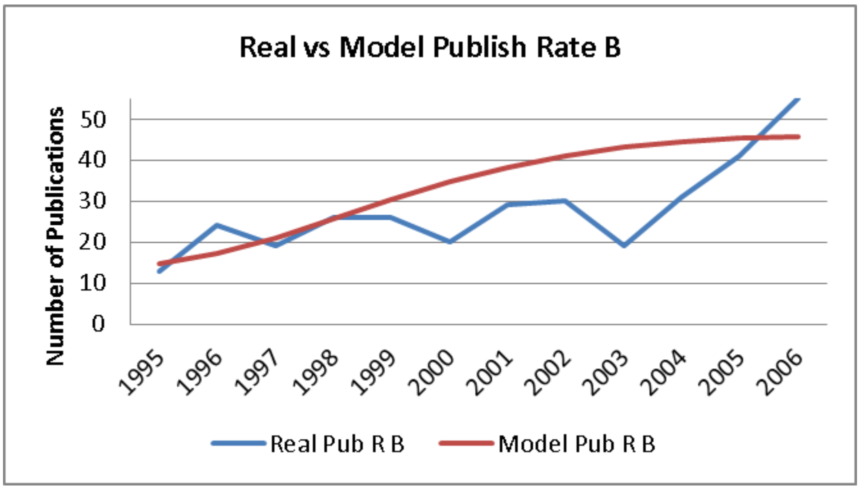

Figure 7.21. Real publish rate vs model publish rate B

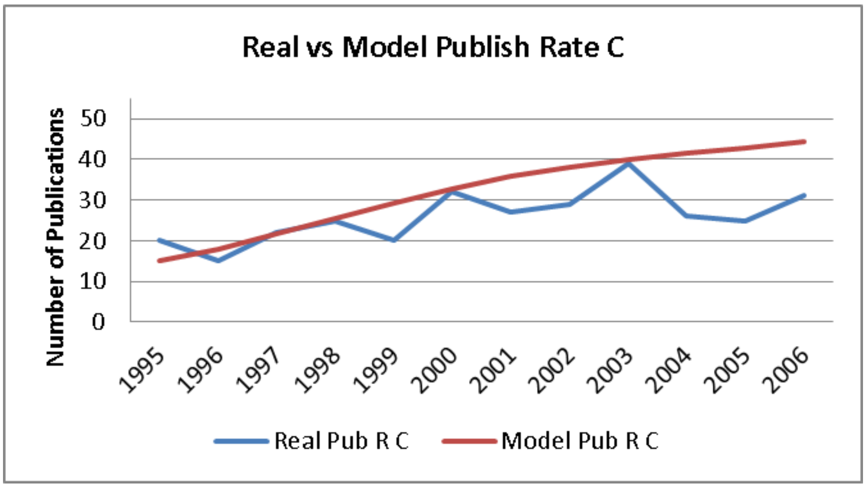

Figure 7.22. Real publish rate vs model publish rate C

7.2.2.3. Average Pub / F/ y. In calculating *average publication per faculty per year* parameter, 3 year moving average method is employed in both real data and model results (Figure 7.23). Real values and model results are close.

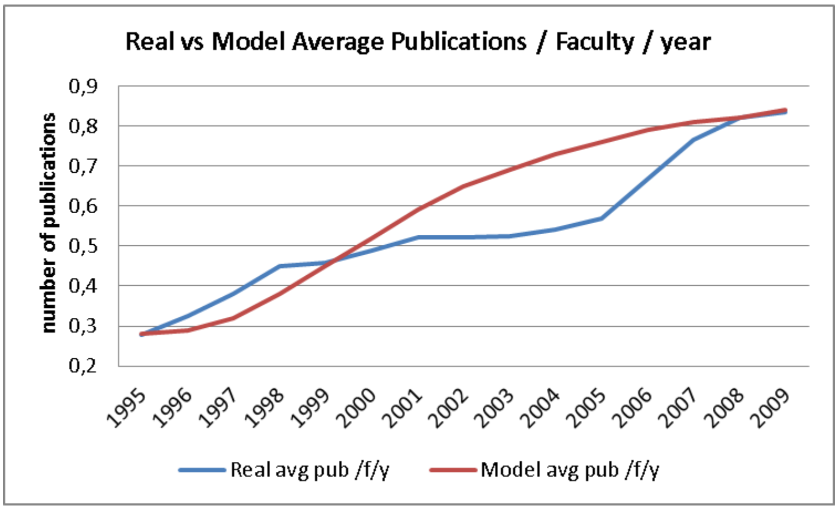

Figure 7.23. Real vs model average publication/faculty/year

7.2.2.4. Research Time. Estimated real research time and *research time* in the model are seen in Figure 7.24. In the model, *research time* values seem higher than real values during the analysis period. However, the gap between real and model values are not too big to violate our study. Although the values are not exactly the same, the increasing behavior in both curves are similar.

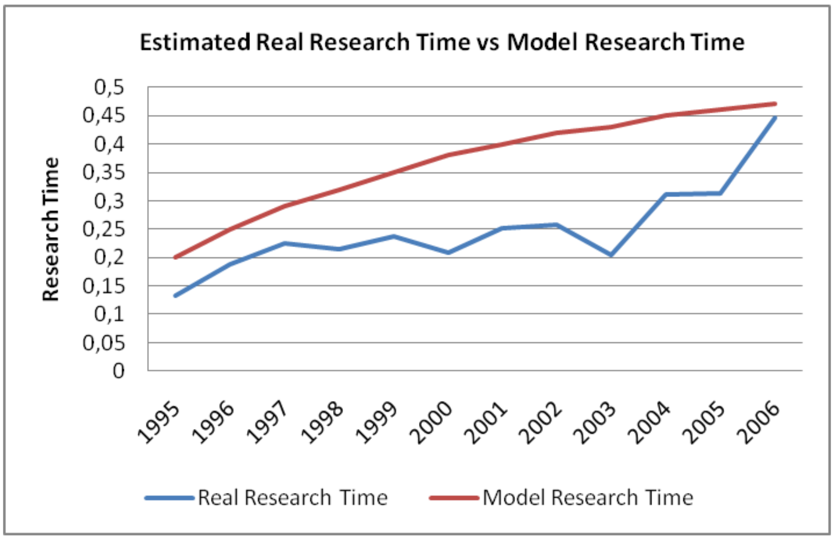

Figure 7.24. Estimated real research time vs model research time

<u>7.2.2.5. Fractions of Research Time.</u> *Fraction of research time for A type research* is seen in Figure 7.25. *Fraction of research time for B type research* is seen in Figure 7.26. *Fraction of research time for C type research* is seen in Figure 7.27. In all three figures, it is seen that, there is not an apparent increase or decrease in real life behaviors. The model consistently reproduces the real life values for all three fractions of research time.

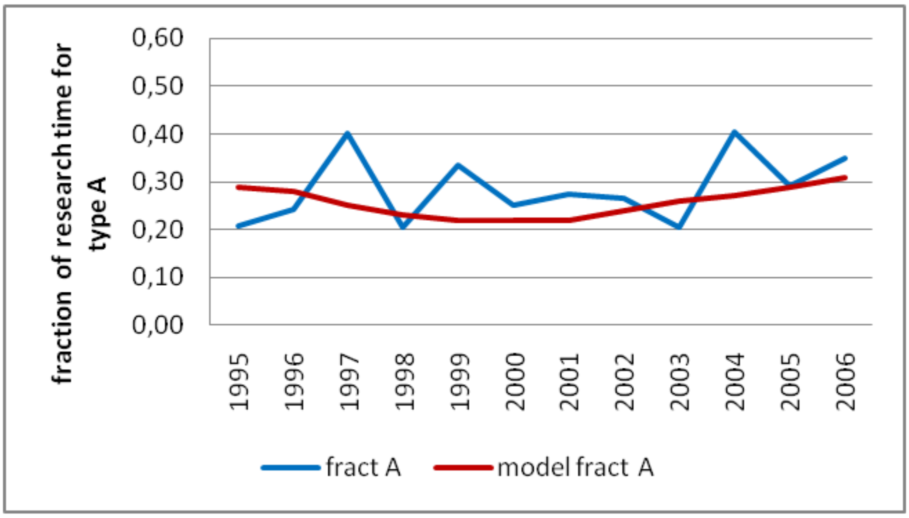

Figure 7.25. Estimated real fraction of research time vs model fraction of research time for type A

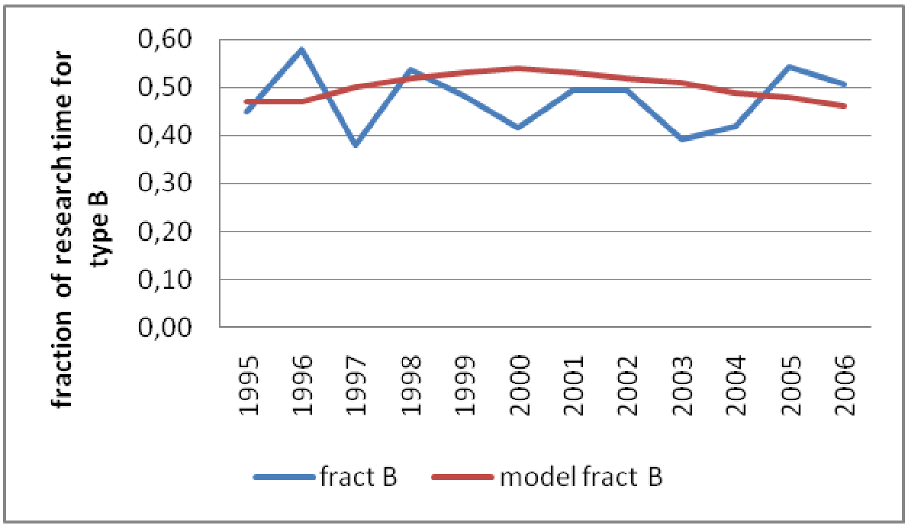

Figure 7.26. Estimated real fraction of research time vs model fraction of research time for type B

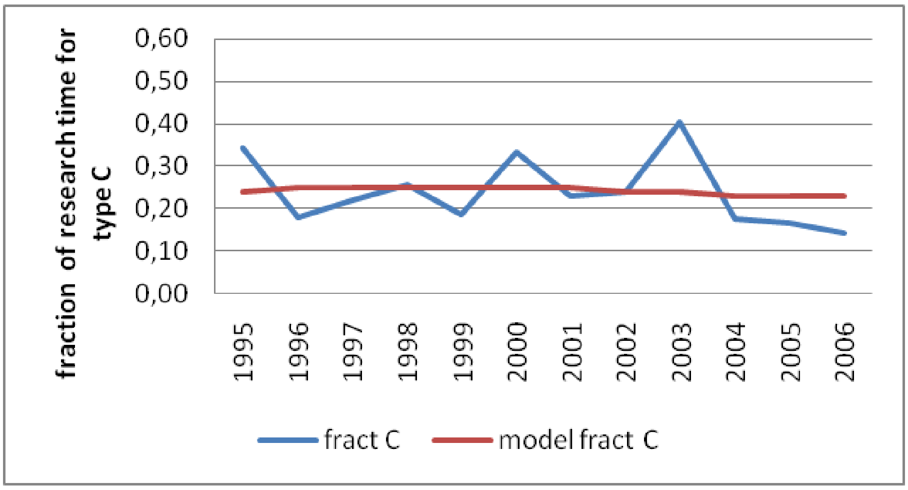

Figure 7.27. Estimated real fraction of research time vs model fraction of research time for type C

7.2.3. Citation Rate

Real citation receiving rate data is taken from Web of Science. The increasing behavior of citation rate is seen in Figure 7.28. Web of Science provides the curve from 1992 to 2010.

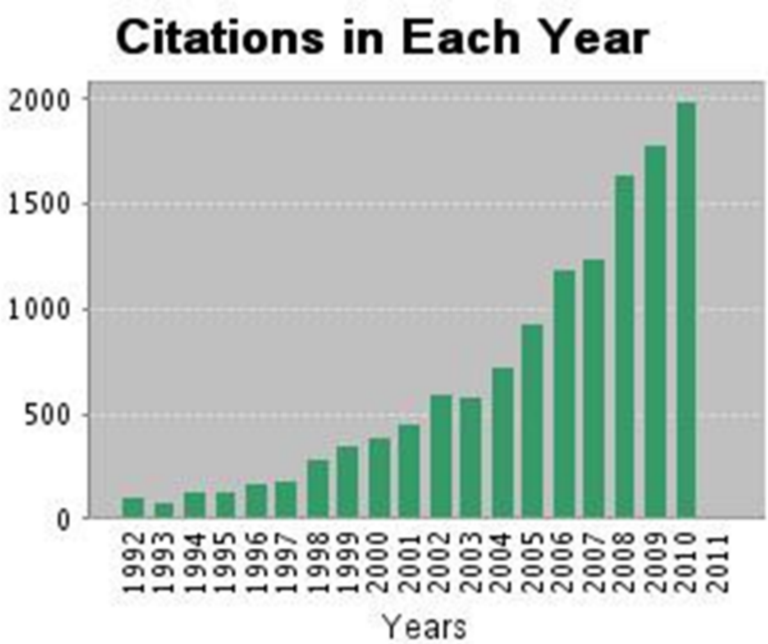

Figure 7.28. Citations in each year

In the model, *citation receiving rate* is almost the same as real citation receiving rate. The behavior is seen in Figure 7.29. Although Web of Science provides the curve from 1992 to 2010, the model is started to run in 1995, so in the figure for real values, 1995 is taken as the starting year.

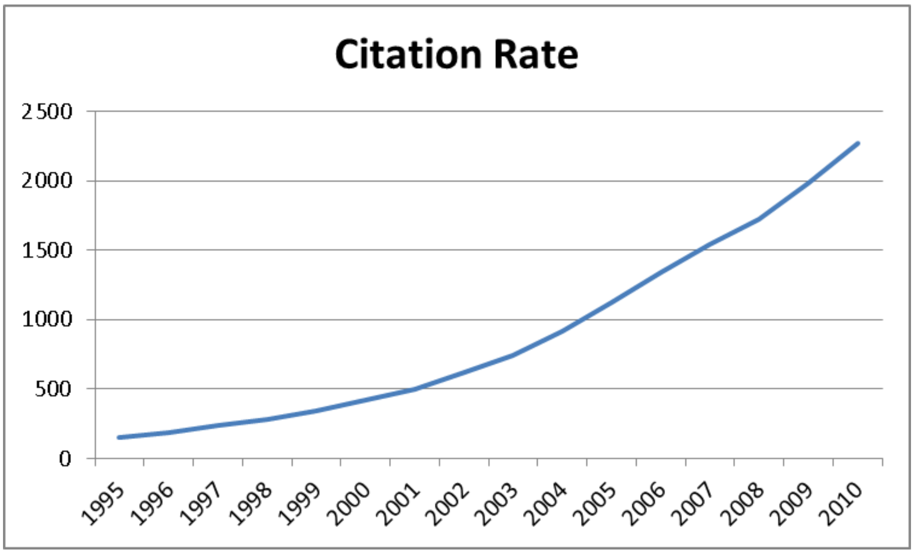

Figure 7.29. Model citation rate

Real average citation per publication in 2010 is given as 9.59 in Web of Science where it is calculated as 3.14 based on Web of Science publications at the beginning of 1995. In the model, average citation per paper is 9.32 in 2010 where it is 2.84 at the beginning of 1995.

8. SCENARIO AND POLICY ANALYSIS

8.1. Scenario Analysis

8.1.1. Scenario 1: Skill level improving over time

In the model it is assumed that, *skill* level of faculty is a given feature of faculty. Once we decide on a faculty body to simulate, we give its skill level to the model and continue with that.

In this scenario, it is assumed that, *skill* level is changed by some internal effects. The internal effects can be counted as experience gained by publishing publications, age, hiring new more skilled faculty members etc.

In the model, no internal effect formulation is done; rather skill level is increased from 50 to 65 gradually after year 2006. The increase in the skill level represents the overall effect of possible internal factors counted above.

Skill has a positive effect on *paper writing rate* assuming that high skilled researchers are able to finalize their research in shorter time than low skilled researchers. The high *paper writing rate* provides a high *publish rate*. Increased *average number of publication per faculty per year* results in lower publication pressure on researchers (Figure 8.1).

When faculty members realize that they are publishing more than before even though they are spending less time on each publication, they lower the time they devote on research activities (Figure 8.2).

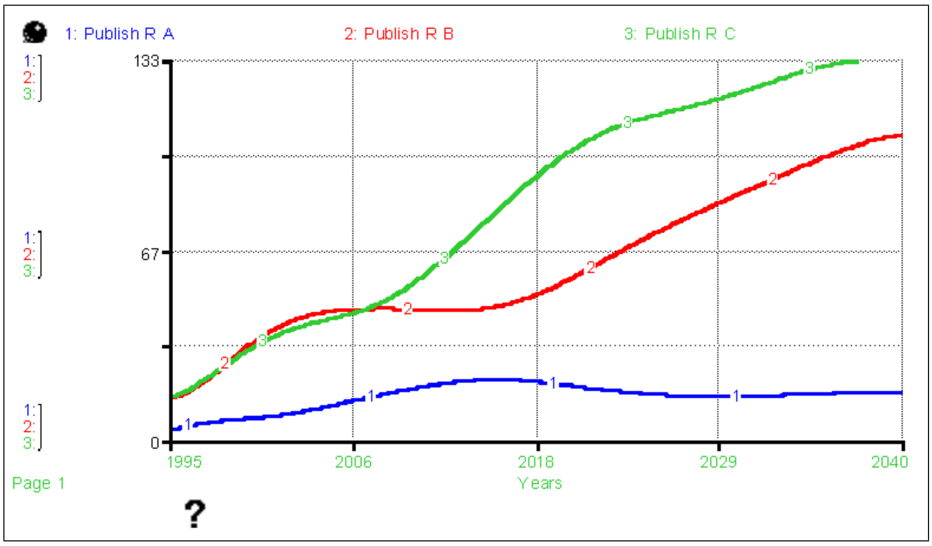

Figure 8.1. Publish rates in scenario 1

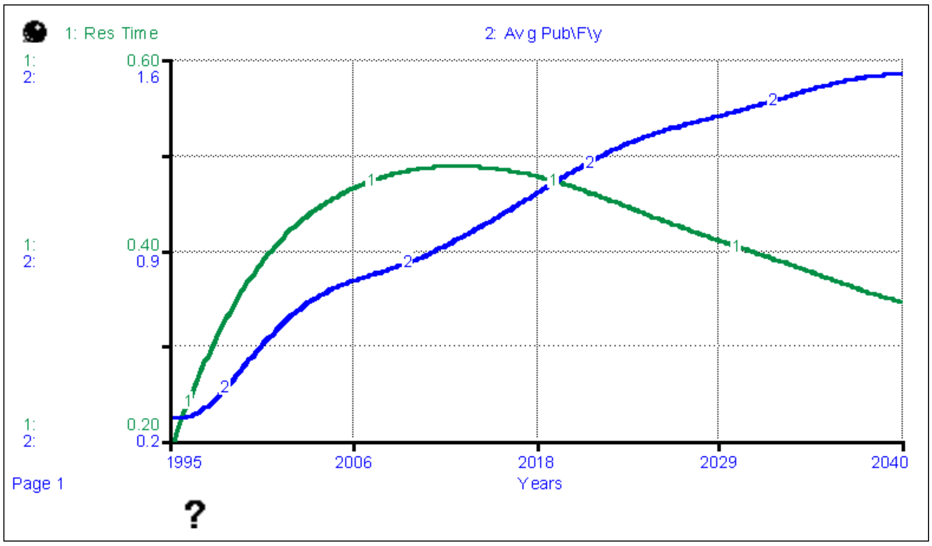

Figure 8.2. Research time and average publication per faculty per year in scenario 1

Fract of Res t for C increases at most to 0.36 in 2019 and then, when the decrease in publication pressure is felt by faculty members, it starts decreasing. Its final value is 0.32. *Fract of Res t for A* stabilizes at a higher value than its value in base run. The reason is the weak publication pressure. Nevertheless, it does not reach very high values either because; citation pressure is not very strong as well. Rather than *A type* or *C type research*, faculty members tend to make *B type research* with the absence of both of the pressures (Figure 8.1).

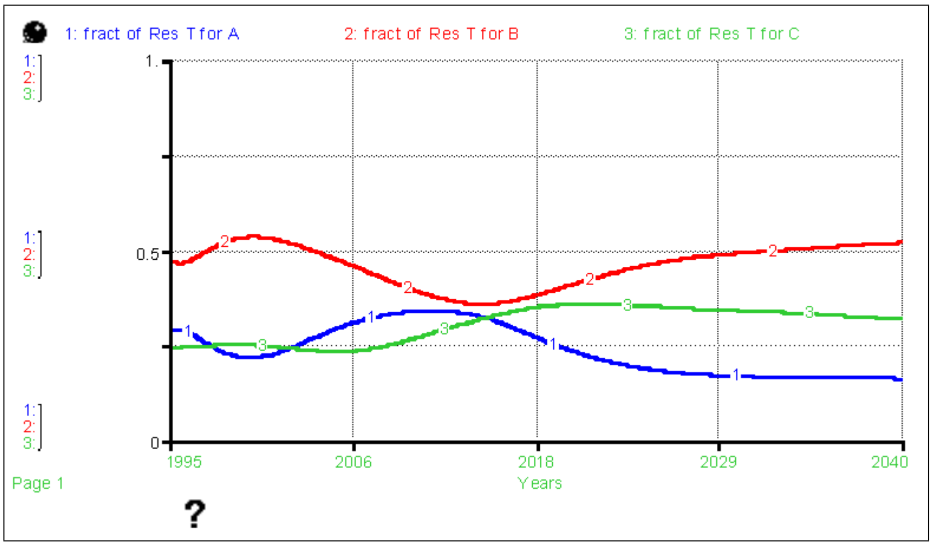

Figure 8.3. Research time allocation in scenario 1

Average citation per publication values increase very much. The reason of this increase is twofold. Firstly, *skill* has a positive effect on *citation receiving rate*. As explained in description of skill sector, average number of citations a publication receives in a particular kind of journal is obvious. However, publications of high skilled faculty members receive more citations than average. In the same manner, publications of low skilled faculty members receive less citations than average. Secondly, once *citation receiving rates* increase, *reputation* starts increasing. The positive feedback loop works here and high *reputation* level makes *citation receiving rates* higher (Figure 8.4).

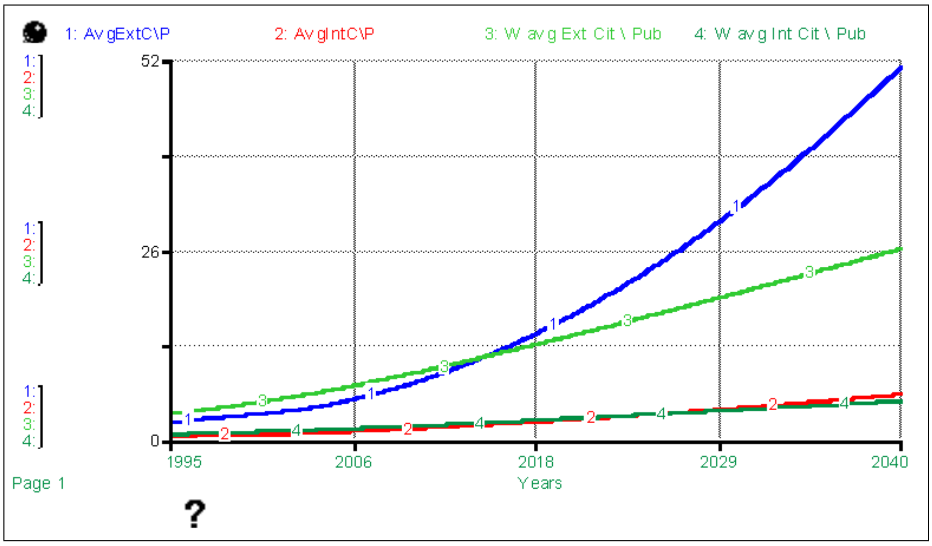

Figure 8.4. Citation per publication in scenario 1

The final values of selected variables in base run and in scenario 1 are presented in Table 8.1.

Table 8.1. Final values of selected variables in base run and in scenario 1

	Base	**Scenario 1**
Fraction of Research Time (fA-fB-fC)	0.15 – 0.46 – 0.39	0.16 – 0.52 – 0.32
Research Time	0.43	0.34
Avg Pub / Faculty / Year	1.18	1.55
Avg Citation/Publication (internal+external)	43	57
Publish Rate (A+B+C= Total Pub R)	11 + 70 + 116 = 197	17 + 107 + 133 = 257

8.1.2. Scenario 2: Worsened skill level

Besides the possibility of increasing *skill* level, there is the possibility of decreasing *skill* level as well. In this scenario, this possibility is analyzed.

In the model, *skill* level is decreased from 50 to 40 gradually after year 2006.

Publish rates stabilize in lower levels due to low *paper writing rates*. Decreased *skill* level affects *paper writing rates* negatively (Figure 8.5).

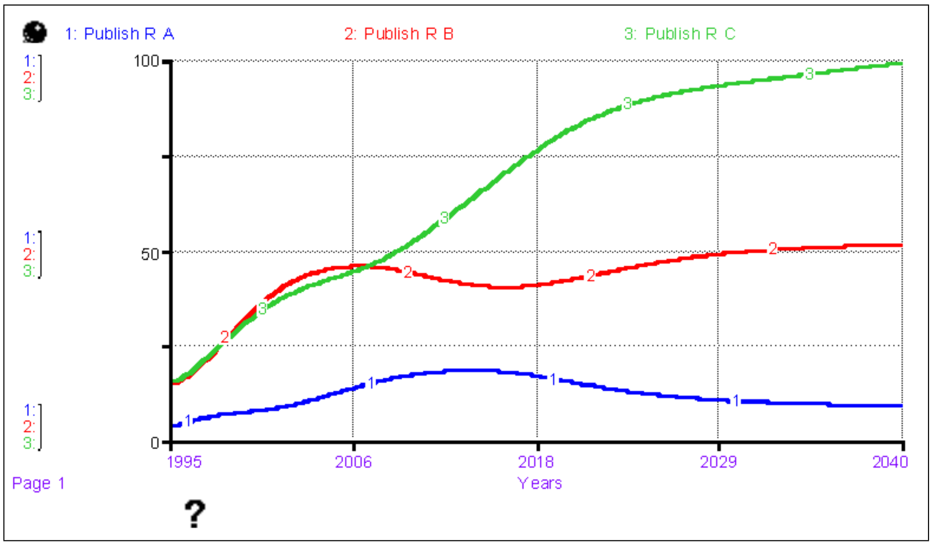

Figure 8.5. Publish rates in scenario 2

Low *publish rates* result in a strong publication pressure. With the publication pressure, faculty members keep the research time at a high level. Although researchers spend very much time on research activities, *publish rates* do not increase very much due to low *skill* level (Figure 8.6).

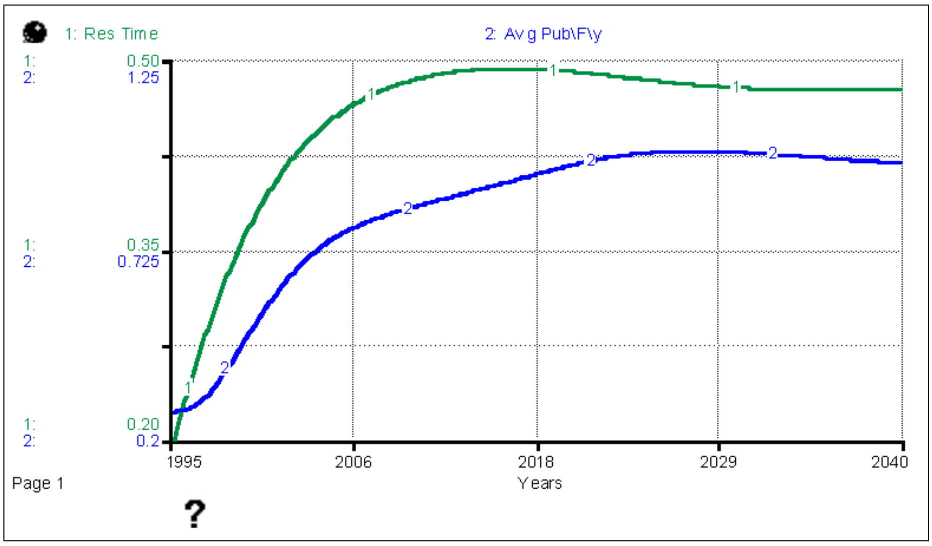

Figure 8.6. Research time and average publication per faculty per year in scenario 2

With the high publication pressure, *fract of Res t for A* stays in a low level. *fract of Res t for B* and *fract of Res t for C* stabilize at high levels (Figure 8.7).

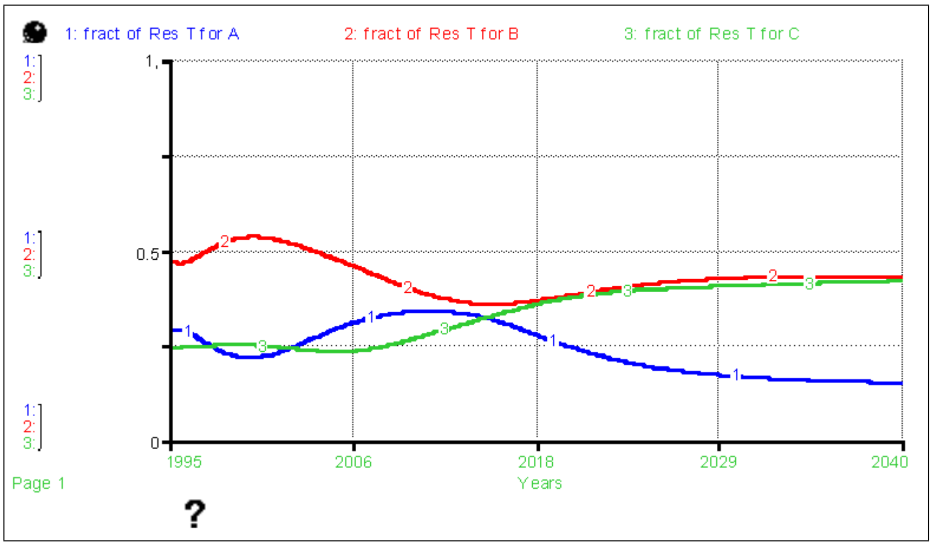

Figure 8.7. Research time allocation in scenario 2

Average citation per publication values are lower than them in base run. However, *external citation per publication* is still higher than world average and *internal citation per publication* is very close to the world average. That is due to the continuing effects of beginning high *skill* level. The previously published high quality publications keep receiving high number of citations (Figure 8.8).

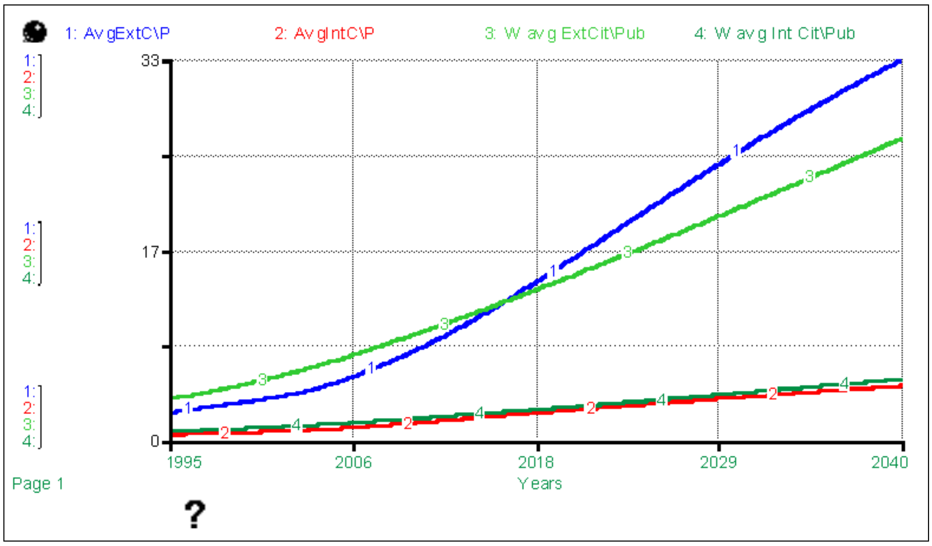

Figure 8.8. Citation per publication in scenario 2

The final values of selected variables in base run and in scenario 2 are presented in Table 8.2.

Table 8.2. Final values of selected variables in base run and in scenario 2.

	Base	**Scenario 1**
Fraction of Research Time (fA-fB-fC)	0.15 – 0.46 – 0.39	0.15 – 0.43 – 0.42
Research Time	0.43	0.48
Avg Pub / Faculty / Year	1.18	0.96
Avg Citation/Publication (internal+external)	43	38
Publish Rate (A+B+C= Total Pub R)	11 + 70 + 116 = 197	9 + 51 + 100 = 160

8.1.3. Scenario 3: Increasing internal citations

Knowing that number of citations per publication is an important performance measure and quality indicator, faculty members hope their publications receive many citations. If the number of citations received by the publications seems unsatisfactory, they may start citing each other's papers or citing their own papers more to reach the intended citation per publication level. It is a fact that, this scenario is a well accepted one in academia. Citation networks have been formed between authors for this purpose recently. Researchers, who are interested in scientometrics, study this citation network phenomenon. In literature review section, results of some of these studies are mentioned.

This scenario will make faculty members cite the previous publications of the faculty more than usual while writing a new paper. In the model, *Int cit /p/y* is increased to two times the base run value. *Eff of Publish R on Int Cit* is removed. This effect was preventing the *internal citation rates* from being unreasonably high. Under this scenario, high *internal citation receiving rates* are allowed.

Under this scenario, *average internal citations per publication* increases. Impact is calculated by dividing number of citations by number publications regardless of paying attention to the kind of citations. Therefore, although a considerable amount of citations are of type internal, impact is high. High impact provides high *reputation*. Increased *reputation* results in high *external citation receiving rates* (Figure 8.9).

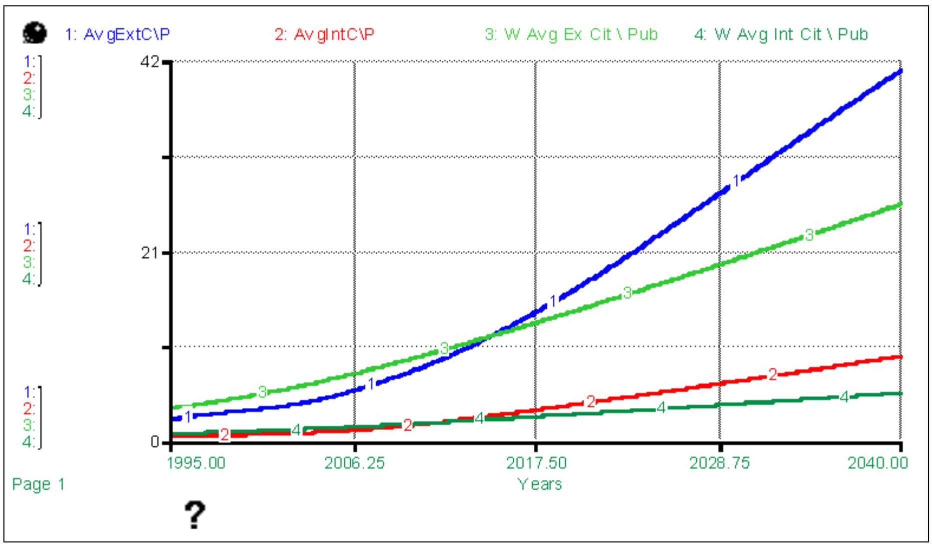

Figure 8.9. Average Citation per Publication values in Scenario 3.

High *reputation* level results in high *acceptance fraction* as well. Thanks to the high level of *acceptance fraction*, *publish rates* are at high levels (Figure 8.10).

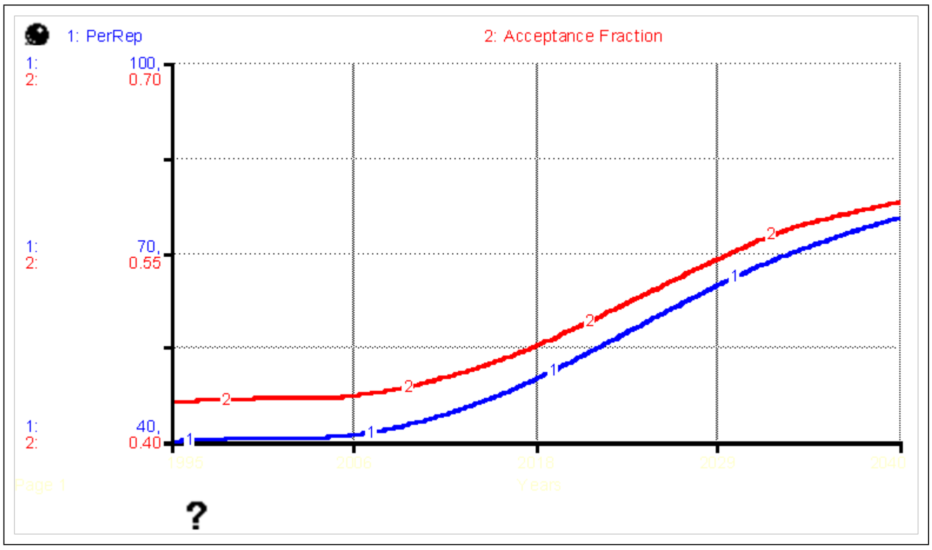

Figure 8.10. Reputation and Acceptance Fraction in Scenario 3.

Since *publish rates* are satisfactory, *research time* stays the same as it does in the base run (Figure 8.11).

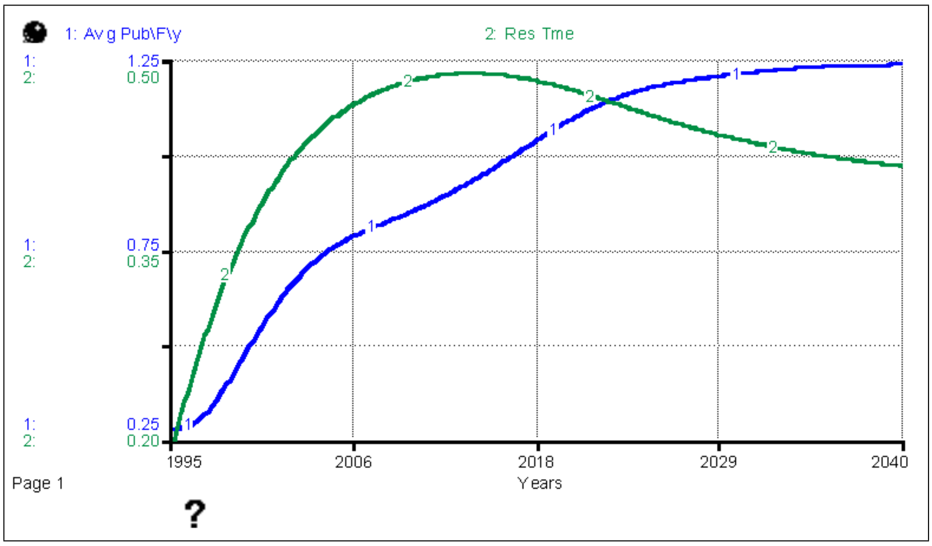

Figure 8.11. Average Pub/f/y and Research Time in Scenario 3.

Citation pressure is not very heavy due to the high citation receiving rates. So, *fract of Res t for A* stays the same. In addition, publication pressure is not very heavy due to high *acceptance fraction* which results in high *publish rates*. Decreased publication pressure allows a slight increase in *fract of Res t for B* in exchange for a slight decrease in *fract of Res T for C.*

Final values of selected variables in base run and in Scenario 3 are presented in Table 8.3.

Table 8.3. Final values of some important variables in base run and in Scenario 3.

	Base	**P4**
Fraction of Research Time (fA-fB-fC)	0.15 – 0.46 – 0.39	0.15 - 0.47 – 0.38
Research Time	0.43	0.42
Avg Pub /Faculty / Year	1.18	1.24
Avg Citation / Publication	43	50
Publish Rate (A+B+C= Total Pub R)	11 + 70 + 116 = 197	12 + 75 + 121 = 208
Avg External Citation / Publication	39	41
Avg Internal Citation / Publication	5	9
Reputation	40->63	40->76
Acceptance Fraction	0.43->0.54	0.43->0.59

Results obtained with this scenario are very satisfactory. Increased *average internal citations per publication* provide an increase in *reputation.* Increased *reputation* results in high *acceptance fraction* and high *external citation receiving rates.* Therefore, both citation receiving performance and publication production performance are satisfactory.

8.2. Policy Analysis

It is a fact that, there is an increasing tendency towards pushing researchers to produce high numbers of publications. There are various motives for this tendency. Publication productivity is connected to tenure decisions or grants are provided to those who publish more. Different policies can be adopted to try to increase publication production performance. With the first two policies, this “publishing more” phenomenon will be handled.

Under the third policy, faculty members will be able to increase their research time in exchange for decreasing the time they spend on other administrative or educational duties which are assigned by university management.

Forth policy is kind of an imaginary policy. It tells that, faculty members should do research for only high quality outcomes. Number of publications per faculty is of very low importance, but quality is everything.

While performing new policies, the first 11 years of the simulation is not violated since those years are based on real behavior of faculty. Policy analysis aim at finding out policies, which will take the faculty to better positions in terms of quality and performance in the future.

8.2.1. Policy 1: Upgrading the publication benchmark

The reason of the emergence of publication pressure is that, faculty compares its yearly publication production performance with the average yearly publication production in the world considering the world average as a benchmark. Faculty members feel under pressure as long as they are below the world average. In the base run, it is seen that, taking world average as the benchmark did not make faculty members very well performed publication producers regarding number of yearly publications.

The policy makers in the school may select a different benchmark hoping a better publication production performance. For that purpose, *world avg pub/f/y* parameter, which is compared with *avg pub /f/y* is gradually increased from 1.57 to 3 throughout the simulation period.

By increasing the performance measure, which is the direct source of publication pressure, publication pressure increases. Increased publication pressure causes *research time* to increase as well. The increasing behavior of *research time* is seen in Figure

8.12. In the base run, *research time* was increasing at first, but in time, when *avg pub/f/y* reaches a satisfactory level, publication pressure decreased and *research time* saturated at a lower level, 0.43. This time, *research time* started to increase and never decreased again. Saturation occurred at level 0.53, which is much higher than that in the base run (Figure 8.12).

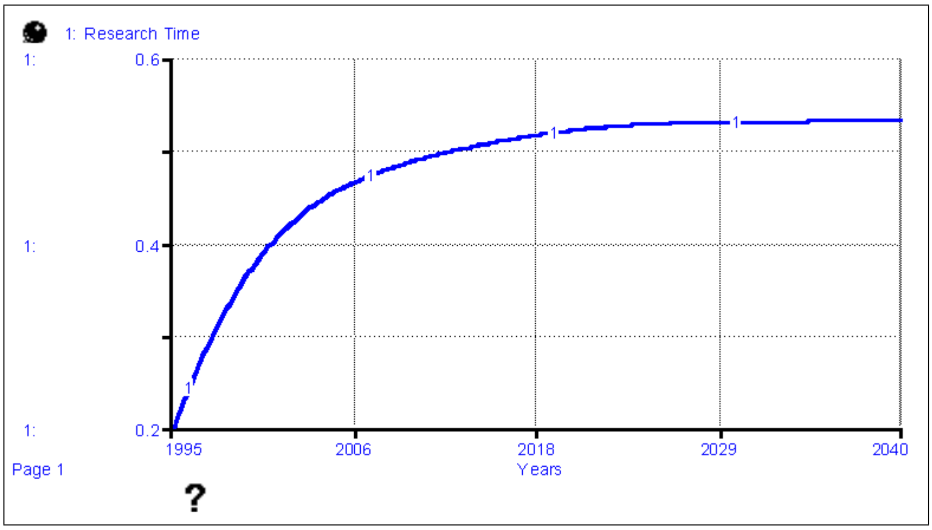

Figure 8.12. Research Time under Policy 1

Allocation of research time with this policy has a very different behavior than the base run allocation. *fract of Res t for A* decreases to a lower level and *fract of Res t for C* becomes very high (Figure 8.13).

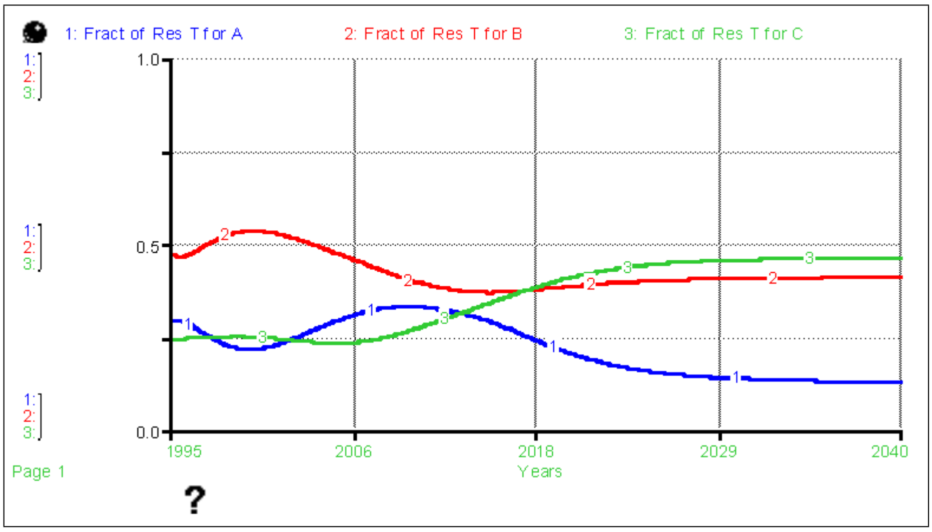

Figure 8.13. Research Time allocation under Policy 1

Although *fract of Res t for A* and *fract of Res t for B* decrease, *publish rate A* and *publish rate B* stay almost the same as base run values because research time is increased. *Publish rate C* increases lot (Figure 8.14).

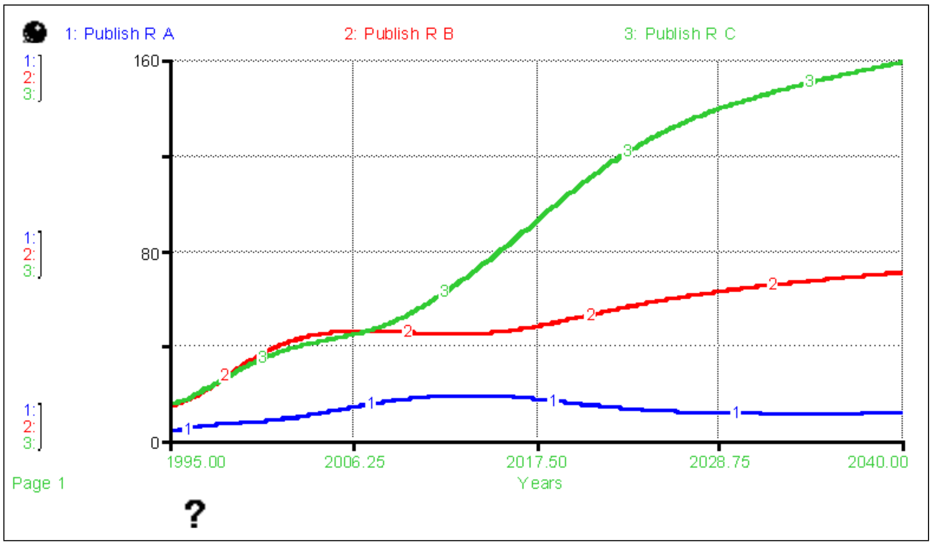

Figure 8.14. Publish Rates under Policy 1

Increased *Publish Rate C* provides a high number of *avg pub /f/y* (Figure 8.15).

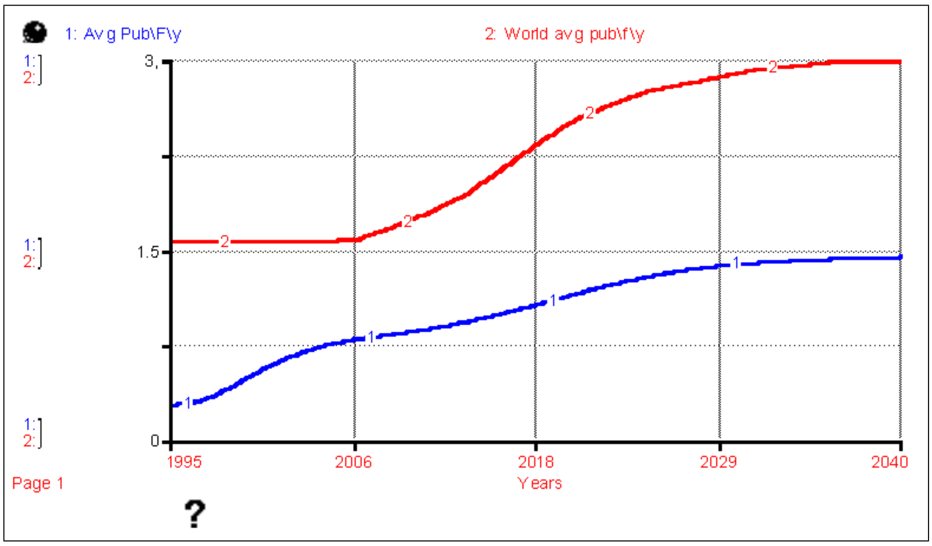

Figure 8.15. Average publication per faculty per year under Policy 1

The final values of selected variables in base run and under policy 1 are presented in Table 8.4.

Table 8.4. Final values of some important variables in base run and under Policy 1

	Base	**P1**
Fraction of Research Time (fA-fB-fC)	0.15 – 0.46 – 0.39	0.13 – 0.41 – 0.46
Research Time	0.43	0.53
Avg Pub / Faculty / Year	1.18	1.44
Avg Citation / Publication	43	37
Publish Rate (A+B+C= Total Pub R)	11 + 70 + 116 = 197	11 + 71 + 160 = 240

In the table, it is seen that, although *avg pub/f/y* reaches a higher level, *avg cit/pub* is at a lower level compared to base run. The reason is that, with this policy, *publish rate C* increases while *publish rates A* and *B* stay the same. *C type publications* do not get as much citations as *A type* or *B type publications.* Therefore, compared to base run, increase in *publish rate* is much higher than increase in *citation receiving rate.*

This policy brings the behavior what it is intended to do, so this is a successful policy. Motivating the faculty members by comparing them with not an average value but with very good benchmark values makes faculty members increase their overall *research time.* They continue publishing *A type* and *B type publications*; in addition, they publish many more *C type publications. avg cit/pub* being in a lower level may seem worrying but although it's level is lower than that in base run, it is still higher than *world avg cit/pub.*

8.2.2. Policy 2: Stronger Publication Pressure

In order to make the faculty members publish more, the strength of the publication pressure on research time allocations can be increased. There may be different ways of doing that. Publication pressure phenomenon is related to the motives of faculty members regarding publication production performance. To motivate the faculty members, benchmark publication production value staying the same which is the *world avg pub/f/y*, being close to benchmark can be rewarded more or being far from benchmark can be punished more.

In this policy, strength of publication pressure on research time allocations is increased. Faculty members are expected to make adjustments in their research time allocation so that their work will make them closer to *world avg pub/f/y*.

The slope of *effect of publication pressure on fract A* and *effect of publication pressure on fract C* are steepen in the model.

Starting in 2006 where the policy is started to be applied, faculty members continuously increase the *fraction of research time that is devoted to C research*. At the end of simulation *fract of Res t for C* almost saturates at level 0.49. Both *fract of Res t for B* and *fract of Res t for A* are decreasing. *fract of Res t for B* decreases to a level which is not very low due to the continuing citation pressure. They try to keep the citation receiving rates at sufficiently high levels. However, *fract of Res t for A* decreases to a very low level. *A type publications* require very much time to be written. Faculty members avoid spending that much time on papers which will not contribute to *pub/f/y* measure very much (Figure 8.16).

Figure 8.16. Research Time allocation under Policy 2

Publish Rate A stabilizes at 7 publications per year which is a very poor quantity.

Publish rate B is almost constant at the equilibrium level of 57 publications per year. *Publish Rate C* increases to 134 publications per year (Figure 8.17).

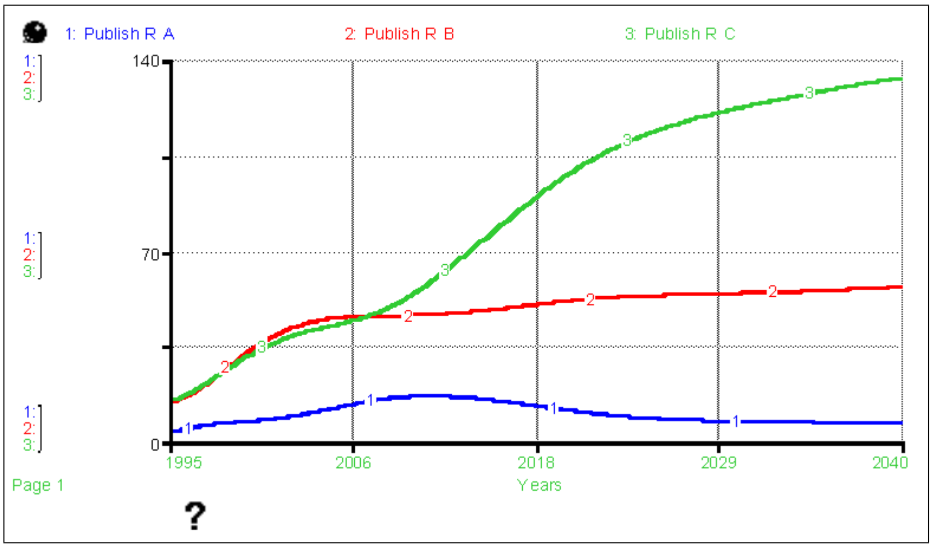

Figure 8.17. Publish rates under Policy 2

Throughout the simulation, *Research time* shows a very similar behavior with it shows in base run, an increase followed by a decreasing saturation. The final level of *research time* is the same as its base run level, 0.43. The reason of not increasing *research time* under this policy is that, publication pressure is stronger than citation pressure. Faculty members believe that reaching the required publication performance level will be adequate; they don't need to worry that much about citation receiving performance. They increase number of yearly publications by only allocating their current research time to C type research rather than A type research.

Although faculty members make the new allocation on the purpose of increasing *avg pub/f/y*, the measure only increases to 1.19 finally. The value of the measure was 1.18 in the base run (Figure 8.18).

The reason underlying the wrong belief of the faculty members is twofold. First, by decreasing *A type* and *B type publish rates* compared to base run, *citation receiving rates* are caused to decrease. Lower *avg citation/ publication level* results in lower *reputation*. And, *acceptance fraction* is lower than that in base run because of low *rep-*

utation level. Secondly, if they were only increasing *publish rate C* without decreasing *publish rate A* and *B*, *total publish rate* would have been increased. But, what they are doing is just trying to increase *publish rate C* while decreasing the other publish rates. This provides only a very minor increase in *total publish rate* and in *avg pub/f/y* measure (Figure 8.19, Figure 8.20).

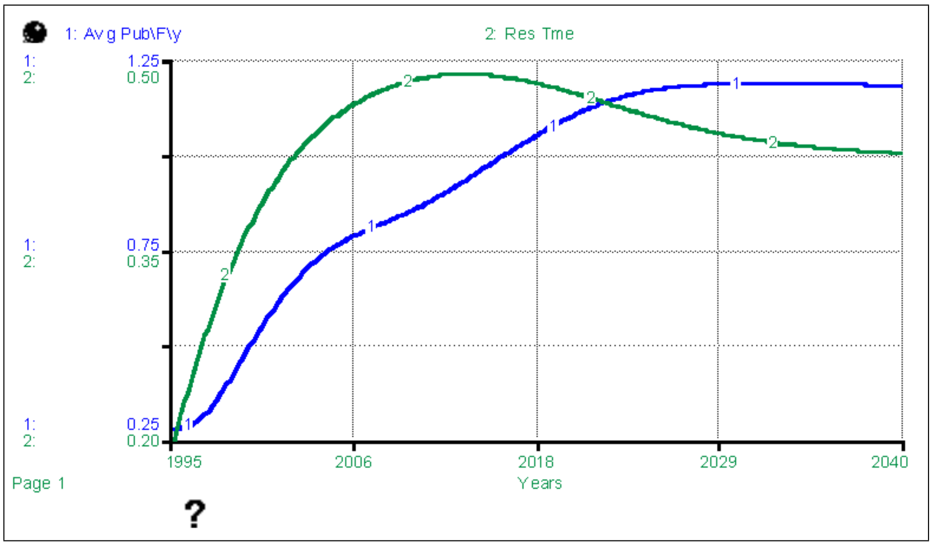

Figure 8.18. Average publication/faculty/year and research time under Policy 2

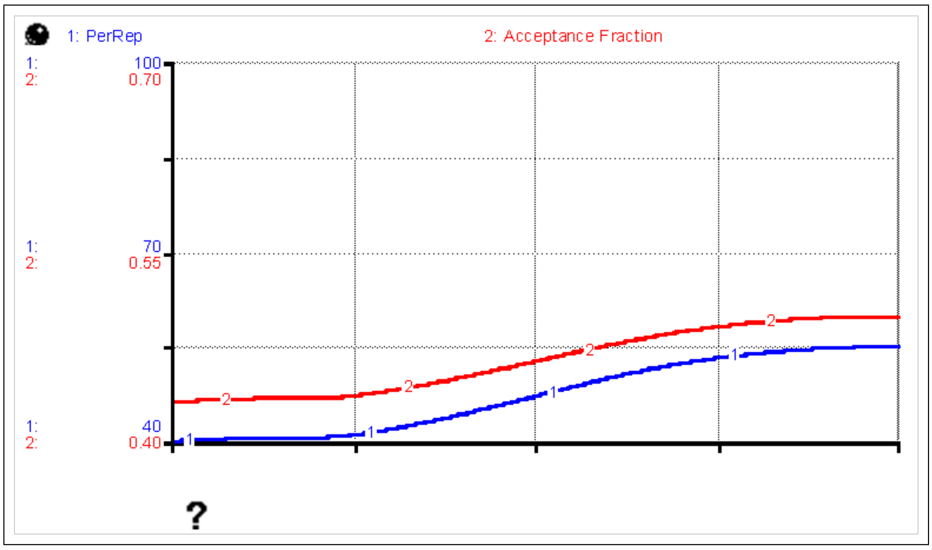

Figure 8.19. Reputation and Acceptance Fraction under Policy 2.

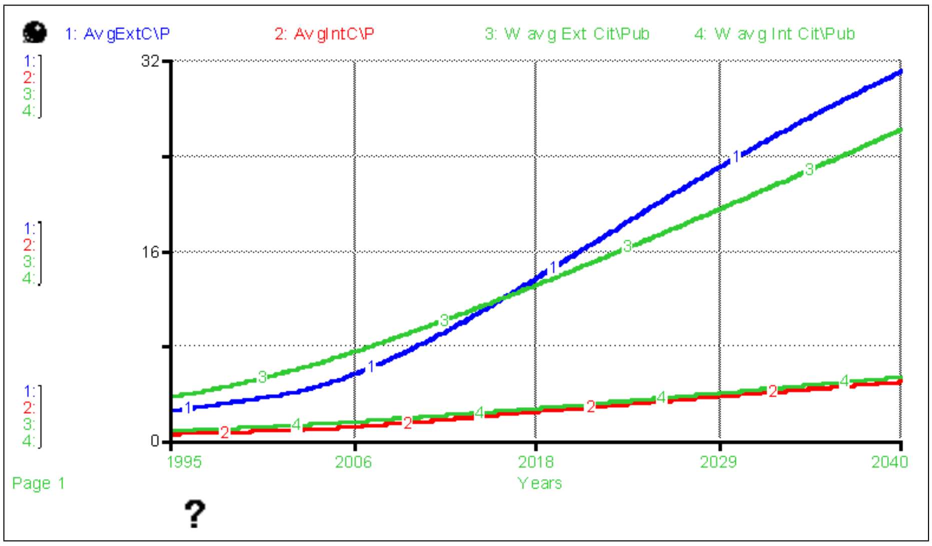

Figure 8.20. Average citation / publication values under Policy 2.

Final values of selected variables in base run and under policy 2 are presented in Table 8.5.

Table 8.5. Final values of some important variables in base run and under Policy 2

	Base	**P2**
Fraction of Research Time (fA-fB-fC)	0.15 – 0.46 – 0.39	0.10 – 0.41 – 0.49
Research Time	0.43	0.43
Avg Pub / Faculty / Year	1.18	1.19
Avg Citation / Publication	43	36
Publish Rate (A+B+C= Total Pub R)	11 + 70 + 116 = 197	7 + 57 + 134 = 198
Acceptance Fraction	0.54	0.50

This policy does not bring what it is intended to do. In order to increase *avg pub/f/y* level, making publication pressure stronger than citation pressure only results in decreasing *citation receiving rates* while *total publish rate* stays the same. All in all, in order to publish in higher amounts, faculty should not ignore high quality, *A type publication* production.

8.2.3. Policy 3: Research Time is affected more from publication pressure.

Publication pressure makes faculty members increase their *research time*. As a new policy, strength of effect of publication pressure on research time can be increased. In addition, change in research time can be done more quickly. This may require arrangements in other loads of faculty members. Faculty members are responsible of attending lectures and they have some administrative loads. Management may take decision about easing some of the loads of faculty members to make them able to increase their *research time* when publication performance is not adequate. So, this policy can be described as, when publication production performance is not good enough, faculty members will increase their *research time* to higher levels than they do in the base run, with a shorter time delay.

Effect of Pub Pressure on Res Time function is steepened and *Research Time AT* is decreased in the model.

The behavior of *Research time* with this policy looks like that in base run but its value is much higher. *Research time* increases very fast and reaches level of 0.59 in 2020. After that with the decreasing publication pressure, *research time* starts decreasing. The final value in the simulation is 0.53 which is much higher than base run value (Figure 8.21).

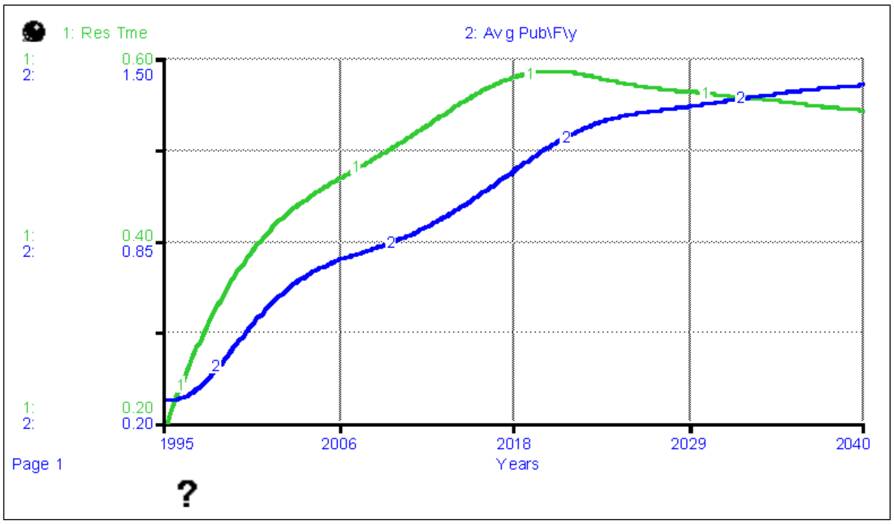

Figure 8.21. Research time and average publication/faculty/year under policy 3

Increased *research time* provides very high *publish rates*. At this point, *publish rates* and research time allocation should be examined together. *fract of Res t for A* makes a similar behavior with it does in base run but the final value of it is 0.17 under this policy. In the base run it was 0.15. This is due to the fact that, with decreased publication pressure, it becomes possible to allocate more time to *A type research*. Similarly, *fract of Res t for B* has a higher value here than it has in the base run. *Publish rate A* and *publish rate B* are very high. This provides high *citation receiving rates*. Although *fract of Res t for C* is at a lower level than it is in the base run, *publish rate C* is higher. That is again due to high *research time* (Figure 8.22, Figure 8.23).

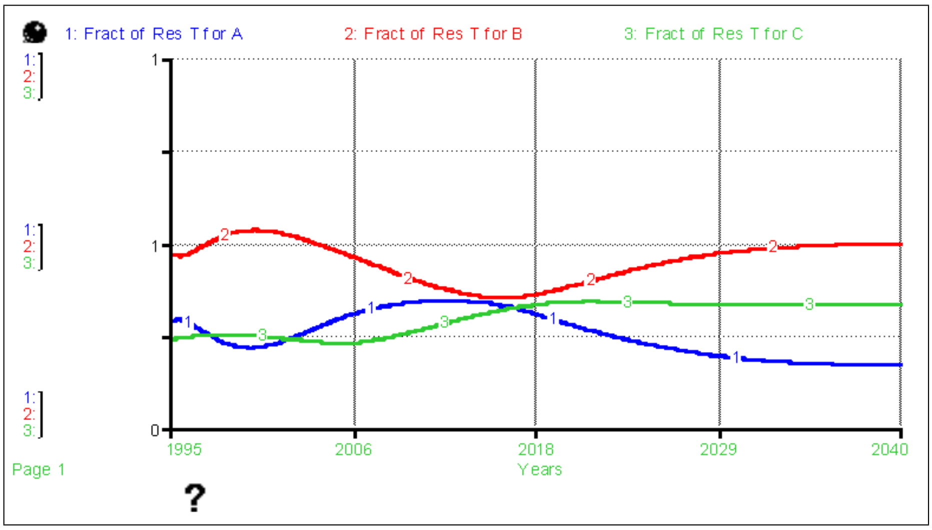

Figure 8.22. Research Time allocation under Policy 3.

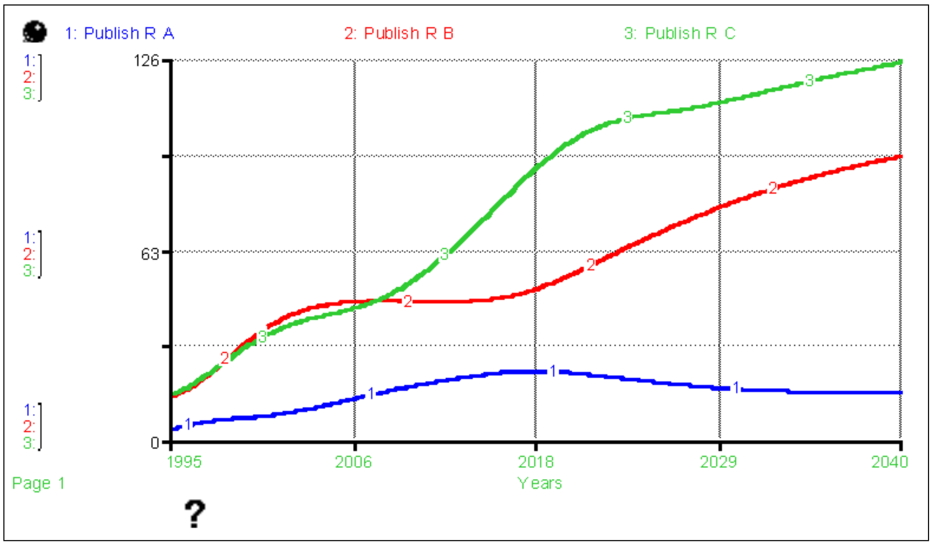

Figure 8.23. Publish Rates under Policy 3

Avg pub/f/y keeps increasing from the beginning to the end. Thanks to that, publication pressure decreases in time. Among all three policies applied up to this point, *pub/f/y* has reached the highest value under this policy (Figure 8.24).

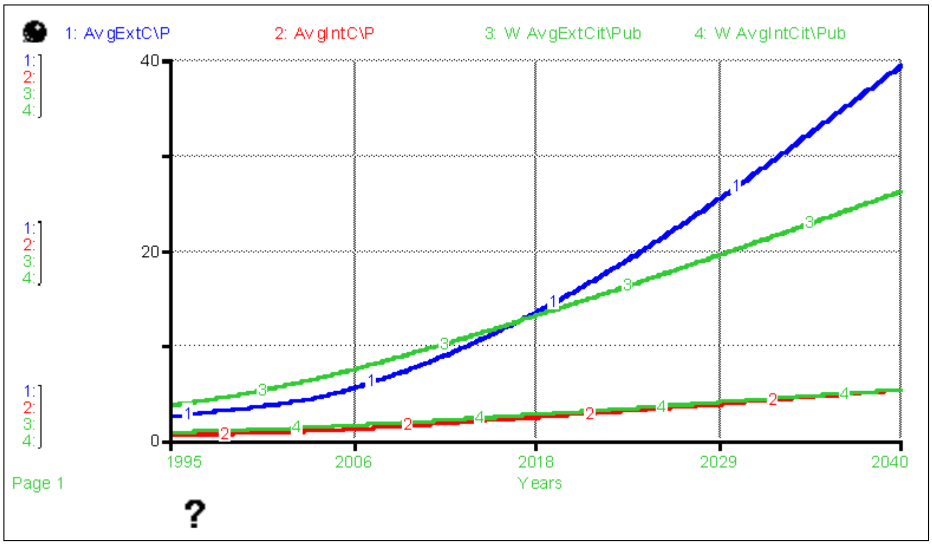

Figure 8.24. Average Citation per Publication values under Policy 3.

Average external and *internal citations per publication* values are high. *Reputation* results in the same level as it does in base run.

Final values of selected variables in base run and under policy 3 are presented in Table 8.6.

Table 8.6. Final values of some important variables in base run and under Policy 3.

	Base	**P4**
Fraction of Research Time (fA-fB-fC)	0.15 – 0.46 – 0.39	0.17-0.50-0.33
Research Time	0.43	0.54
Avg Pub /Faculty / Year	1.18	1.4
Avg Citation / Publication	43	45
Publish Rate (A+B+C= Total Pub R)	11 + 70 + 116 = 197	16 + 94 + 126 = 236
Reputation	63	63

This policy provides faculty members more flexibility about deciding on which kind of research they are going to carry out. Under the previous two policies, researchers had to give up writing *A type papers* because of high publication pressure. However, under this policy, they don't need to give up high quality, *A type papers* but they increase *research time* and write all three types of papers in higher amounts. Both *avg pub/f/y* and *avg cit/pub* measures increase. This means that, both publication production performance and citation receiving performance reach higher levels compared to base run. *Reputation* level turns out to be same with its base run level.

8.2.4. Policy 4: Emphasizing research for Quality

It is in faculty members' hands to decide on how much of *research time* will be devoted to each research category. This policy says that, normally researchers are supposed to do *A type research.* Under publication and citation pressures they adjust their research time allocation but they keep devoting the highest portion of research time to *A type research.* The most important thing is quality. Researchers should not worry much about numbers.

In the model there are normal levels for fraction of research time devoted to each research class. The normal levels are fixed according to current behaviors of faculty members. Citation pressure and publication pressure have an effect on those fractions. The perceived fractions are determined by those effects. In order to apply this policy, the *normal level of fract of res t for A* is increased from 0.3 to 0.6 and the *normal level of fract of Res t for C* is decreased from 0.25 to 0.1 gradually.

Under this policy, *fract of res t for A* reaches its highest value compared to its value under the other policies applied. In 2014, the peak value occurs at 0.44 and it decreases and stabilizes at 0.26 at the end. *Fract of Res t for A* cannot stay at the peak level or go any further because of the increasing publication pressure. Normally, we expect to see *fract of res t for C* to be higher with the publication pressure. But under this policy, publication pressure increases *B type research* rather than *C type research. Fract of Res T for C* is at its the lowest value compared to its value under the other polices applied (Figure 8.25).

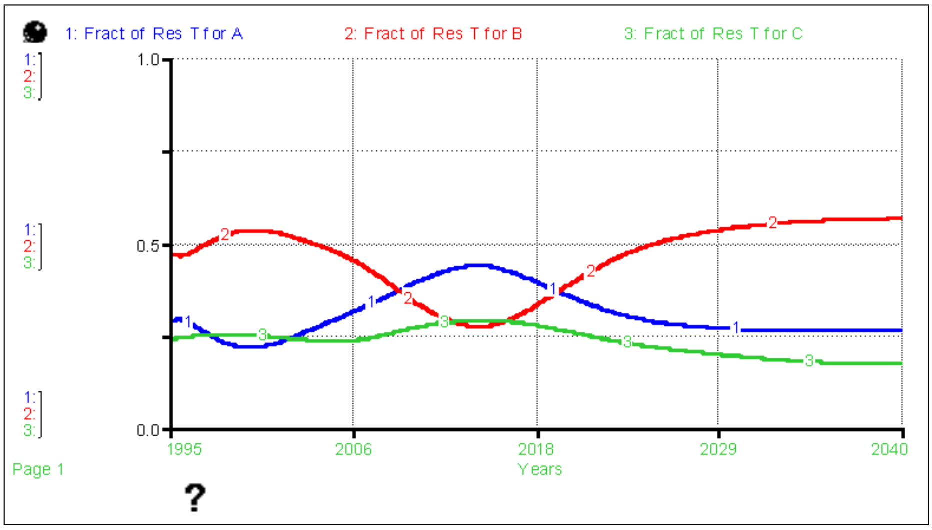

Figure 8.25. Research Time Allocation under Policy 5.

Since *research time* is distributed mainly between *A type* and *B type research*, *publish rates* are lower than them in base run because of the fact that *A type* and *B type publications* require higher time to be written. With the lower publish rates, *pub/f/y* measure is at a lower level which causes publication pressure. This pressure makes research time a little higher (Figure 8.26).

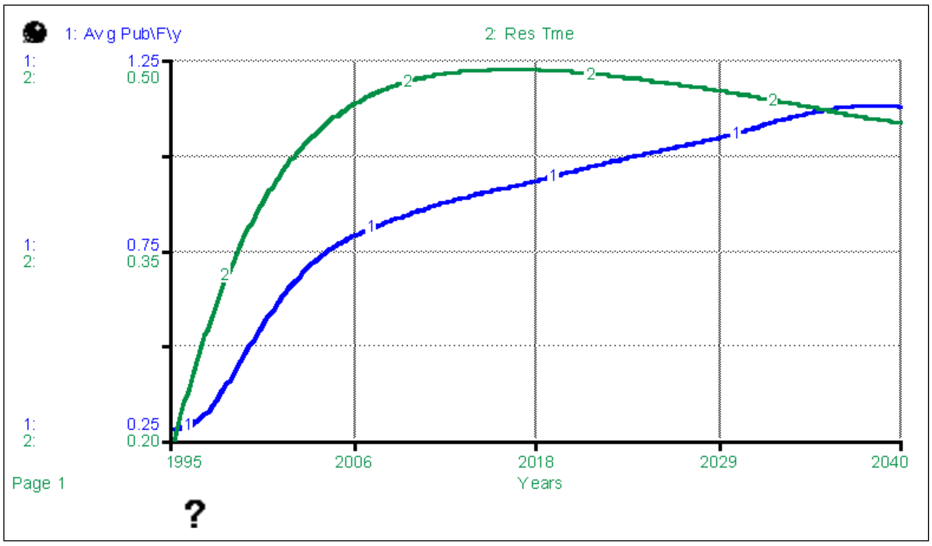

Figure 8.26. Avg Pub/f/y and Research Time under Policy 5.

This policy provides the highest *avg cit /pub* values among all other policies (Figure 8.27).

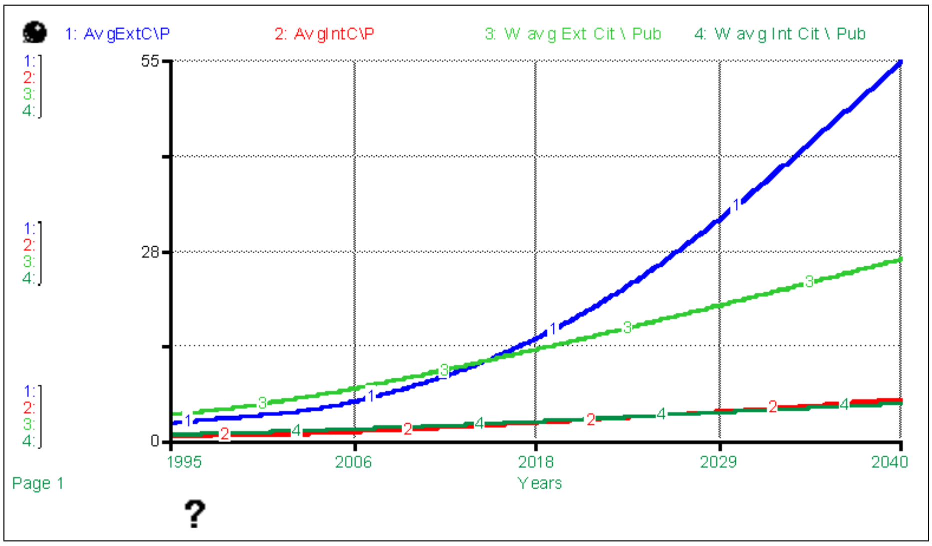

Figure 8.27. Average Citation per Publication values under Policy 5.

Final values of selected variables in base run and under policy 5 are presented in Table 8.7.

Table 8.7. Final values of some important variables in base run and under Policy 5

	Base	**P6**
Fraction of Research Time (fA-fB-fC)	0.15 – 0.46 – 0.39	0.26 – 0.57 – 0.17
Research Time	0.43	0.45
Avg Pub /Faculty / Year	1.18	1.13
Avg Citation / Publication	43	61
Publish Rate (A+B+C= Total Pub R)	11 + 70 + 116 = 197	24 + 102 + 62 = 188

We can say that, this policy provides what it is intended to do. Although *avg pub/f/y* is low, if citation performance is more important than other measures, this policy is good enough to be adopted.

9. CONCLUSION

With the increasing necessity to measure the academic/research performance of scientific institutions, a new field which can be summarized as “measuring science” has emerged. This new science tries to provide objective and comprehensive performance measurement tools. Finding such tools is a difficult, complex task. Moreover, if the measurement tool is inappropriate, measuring of research performance may actually harm research performance. The common concern is that if some formula is dictated to motivate researchers, then researchers would change their research practices in the direction of the formula.

Number of publications and citation impact are two most basic components of performance measure. This study focuses on these two performance measures and investigates the following question: in what directions will the dynamics of publications and citations evolve in the long term, under different scenarios and policies?

A dynamic simulation model is constructed by employing the system dynamics methodology. The system modeled is a complex one consisting of many variables in connection. Reputation of the faculty, skill level, total time devoted to research activities, fraction of the papers accepted by the journals, publication and citation pressure on researchers are the basic variables in the model. Real data from Bogaziçi University and estimations based on the real behaviors observed are used for initializing the model. The model is tested and validated with extensive structural and behavior tests. The model is found successful in reproducing the behaviors observed in real data collected at Bogaziçi University.

The principal aim of modeling this complex system is to find good policies, which will carry the institution to a better position in terms of research performance, while not damaging it in any aspect. For this purpose, extensive scenario and policy analysis are performed.

With the first scenario, we analyzed the effects of increasing skill level of the faculty members. Both the citation and publication performances become better with higher skill level. On the contrary, the second scenario showed that, if skill level decreases in time, both the citation and publication performances become worse.

Encouraging researchers to cite each other more often is an issue in academia. In the third scenario this issue is simulated by encouraging the researchers to give more internal citations. This scenario carries the faculty to a better position in terms of both publication and citation performances. This good performance occurs due to the fact that, having more citations even if they are of internal type, lowers citation pressure on researchers. With the lowered citation pressure, they feel freer to decide what type of research they are going to carry out.

In the policy analysis part, firstly, the well known ‘publish or perish’ approach is handled in the first and second policies. We know that there is an increasing tendency of management to push the researchers to publish more. In the model, publication pressure is exerted on researchers by dictating a benchmark value for the yearly publishing rate. Under the first policy, the benchmark value for yearly publishing rate is increased in time. This made the publication pressure on researchers more persistently perceivable. Researchers tend to increase total time devoted to research activities to catch the dictated benchmark value. This results in an increase in only C type, low quality publications. Through increasing research time, A and B type publications are continued to be published. However, there is no improvement in citation performance, in fact, number of average citations per publication decreases.

With the second policy, the benchmark for yearly publishing rate is not changed, but faculty members are forced to reach the benchmark value in the expense of a decreased citation performance. This makes researchers produce mostly low quality publications, which are written in shorter time. They submit those papers to low quality journals where it is easier to publish papers. Citation performance decreases dramatically, but there is no improvement in yearly publishing rates either. This policy does not bring what it is intended to do.

The third policy examines the situation where the management allows researchers to devote more time on research activities by easing their administrative or educational loads. Under such a policy, researchers become better publication producers. Moreover, number of high quality publications increases remarkably, resulting in increased citations.

Finally, a policy stating 'publish for quality' is examined. The sheer number of publications becomes less important in time. This eventually results in the highest 'citation per publication' value in all experiments. That is to say, if researchers are expected to make high quality research, then if the pressure regarding number of publications is lowered, they act in the expected direction and make high quality research.

The policies are not imaginary, from the literature it is known that they are being applied in various forms in real life. This study provides a platform for analyzing long term behaviors of researchers under different policies regarding citations and publications.

As future research, new factors can be included in the model. Skill level of faculty is an exogenous variable. A good extension of the model can be representing the skill level as an endogenous variable, affected by internal structure of the model. Number of journals covered by ISI has been increasing significantly in recent years. Investigating the reasons underlying the increased number of journals, together with journal impact factor and modeling their dynamic effects may constitute a good extension for the model. An interactive simulation game can be constructed based on this model and decisions of players can be analyzed under publication and citation pressures.

Appendix A: DATA ANALYSIS

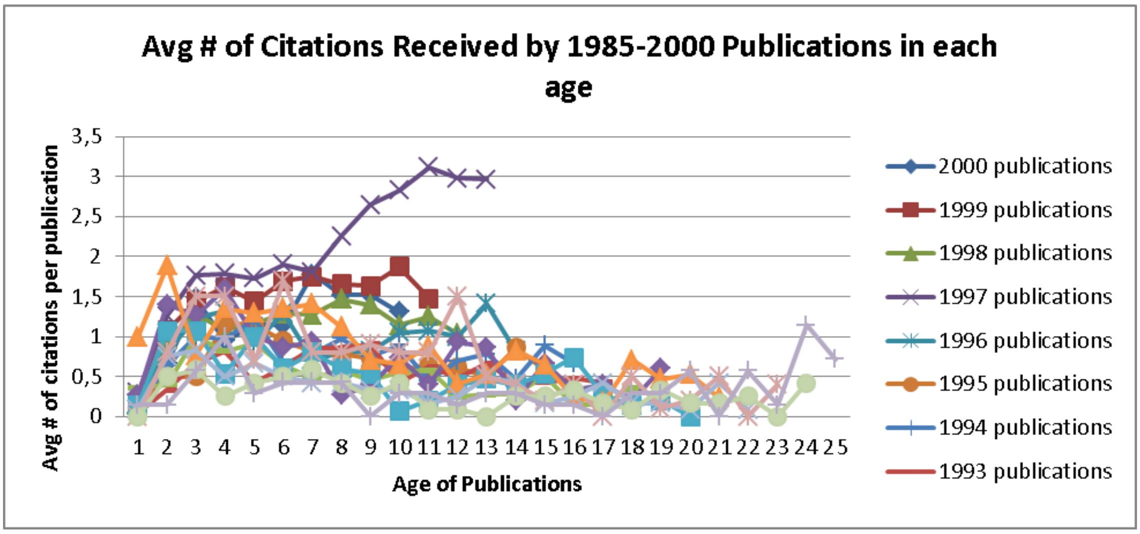

Figure A.1. Average number of Citations received by 1985-2000 publications in each age

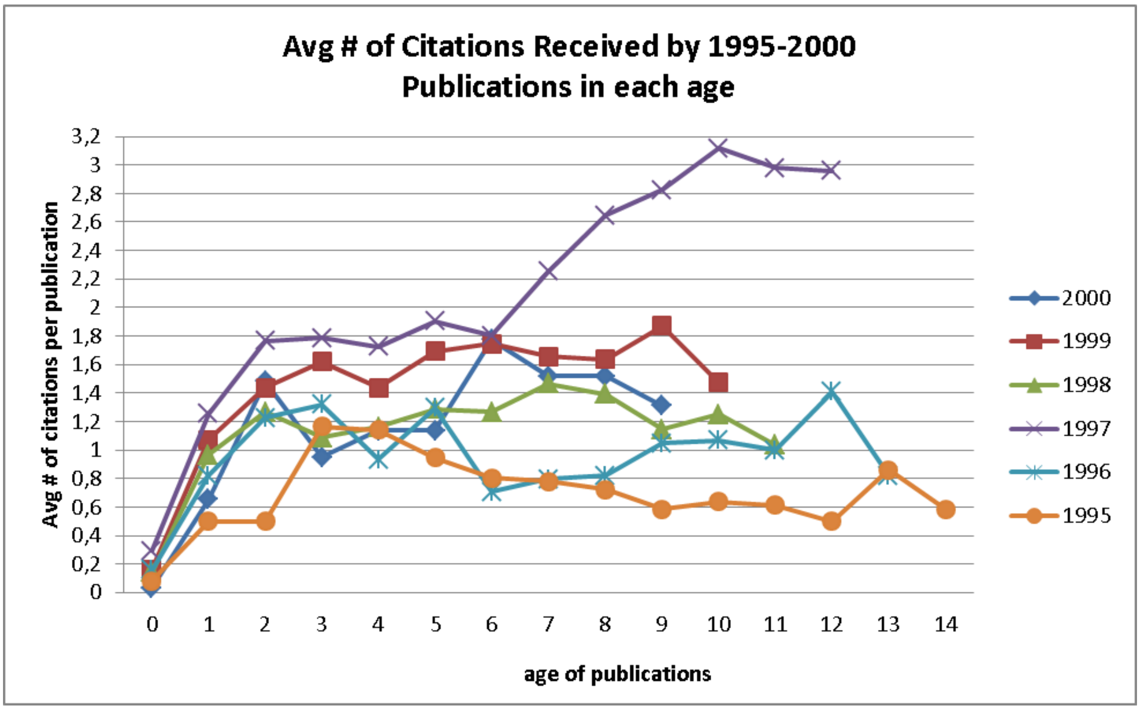

Figure A.2. Average number of citations received by 1995-2000 publications in each age

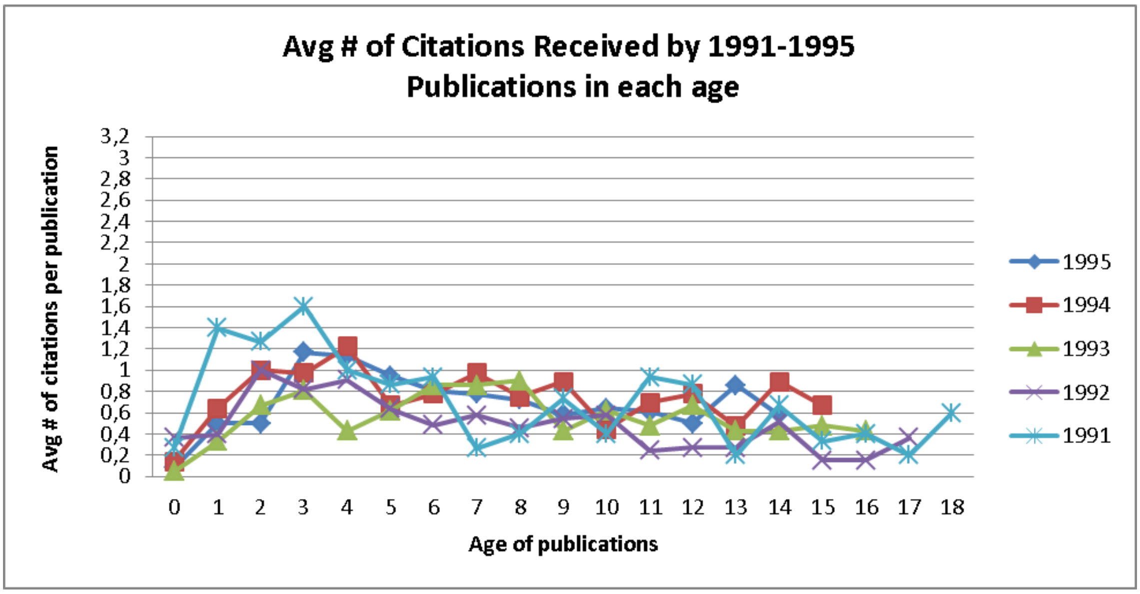

Figure A.3. Average number of citations received by 1991-1995 publications in each age

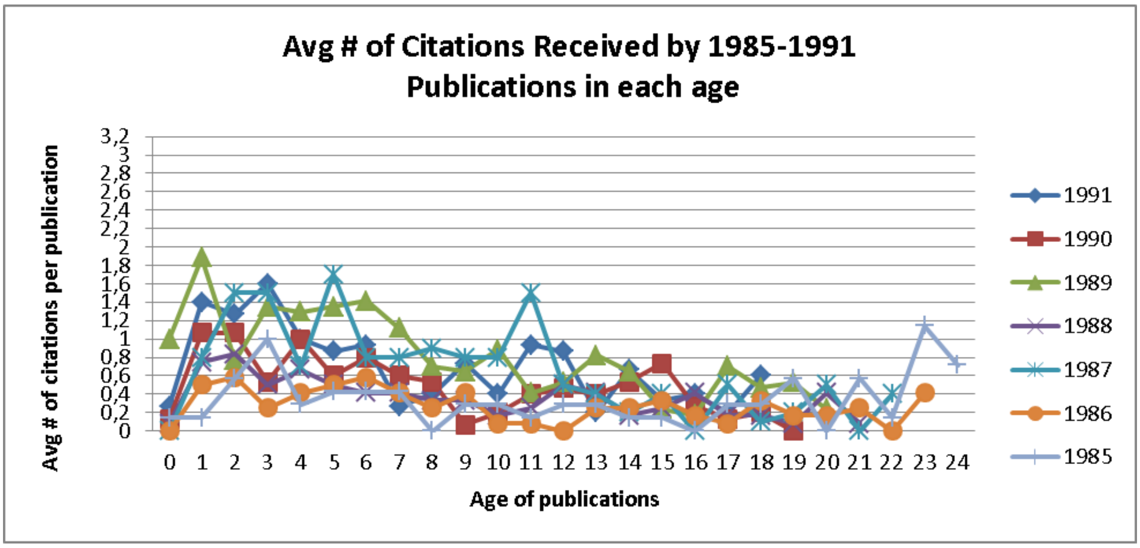

Figure A.4. Average number of citations received by 1985-1991 publications in each age

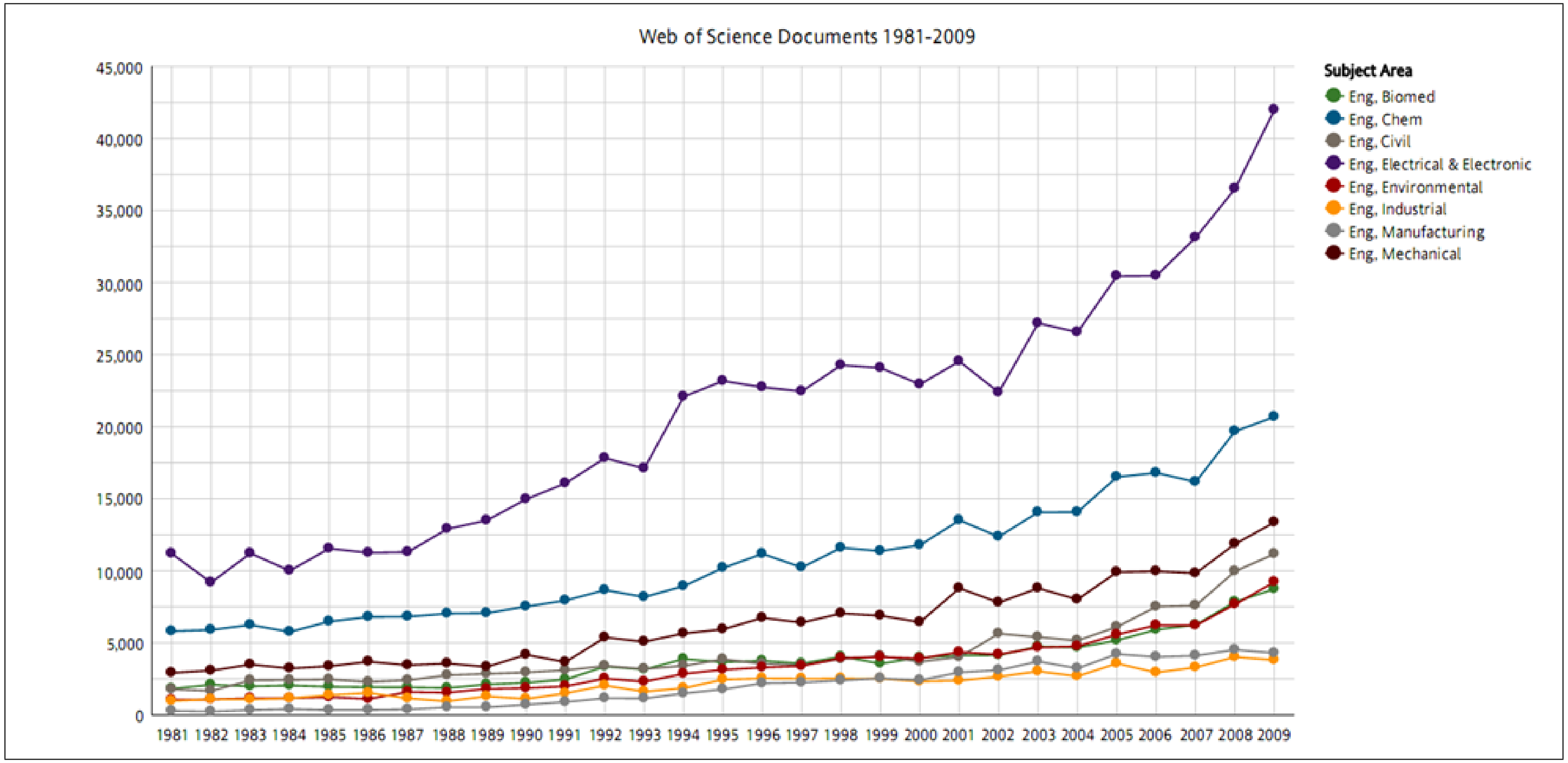

Figure A.5. Number of world publications in each selected engineering field in each year

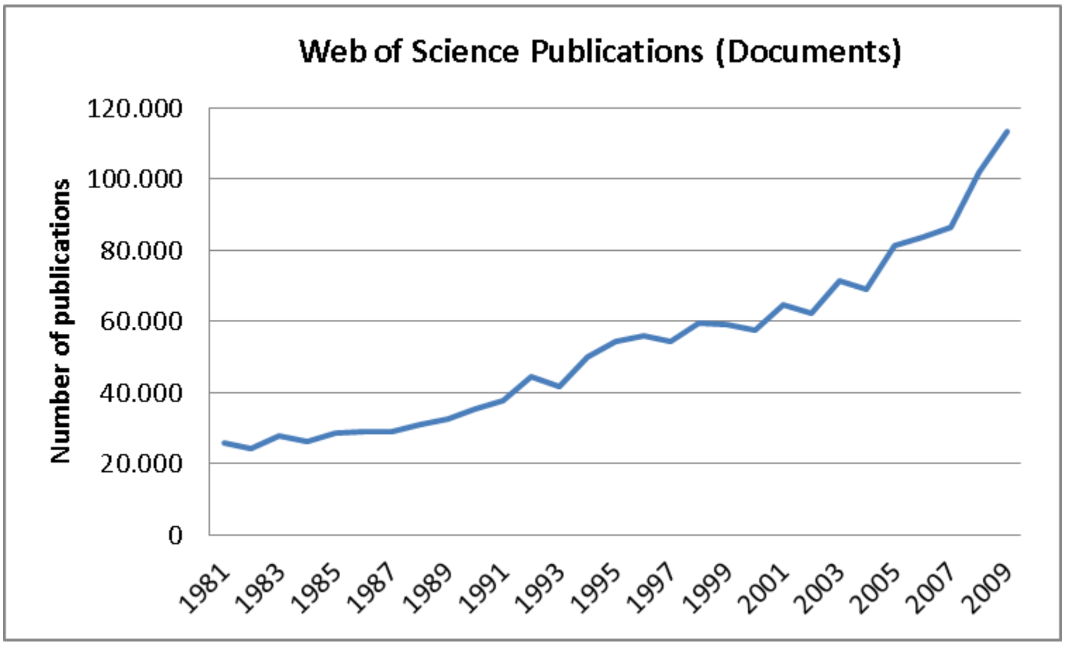

Figure A.6. Total number of world publications of the selected engineering fields in each year

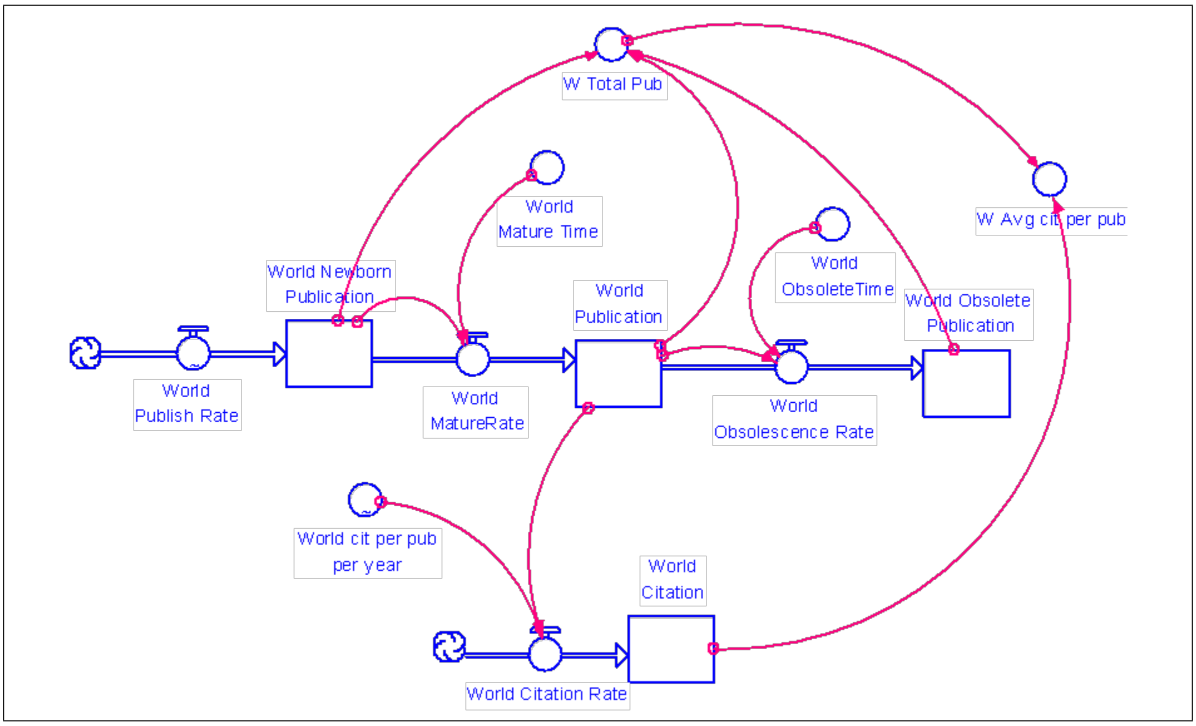

Figure A.7. Simplified World Publications Model

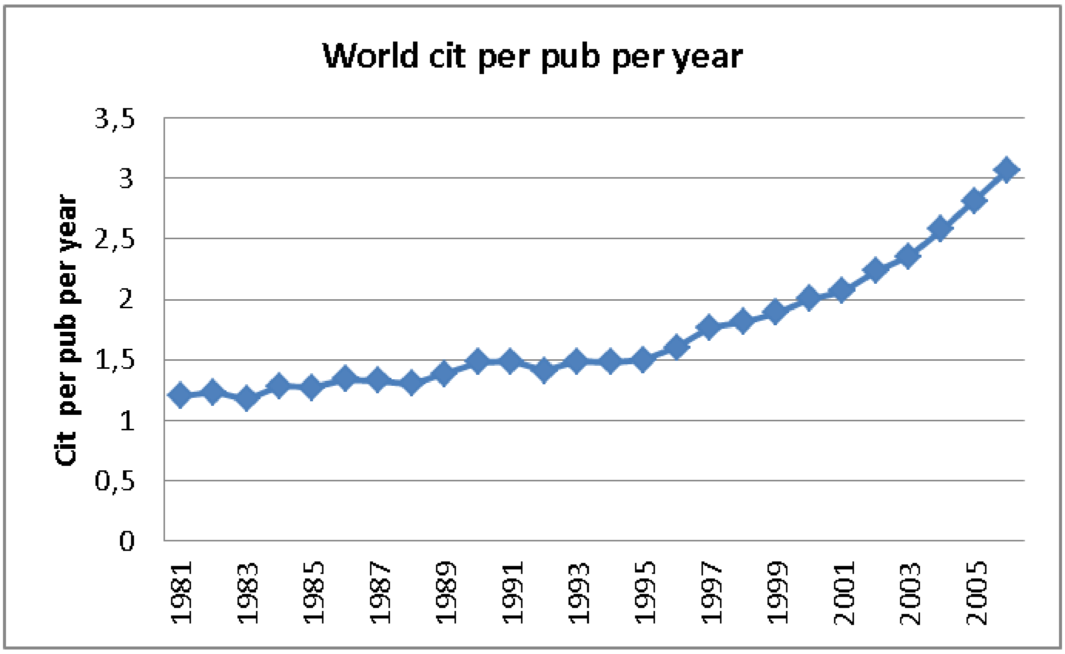

Figure A.8. World cit per pub per year parameter

Table A.1. Regression Analysis: cit per paper per year

Regression Analysis: cit per pub per year versus year

The regression equation is
cit per pub per year = 1.28 + 0.132 year

Predictor	Coef	SE Coef	T	P
Constant	1.28273	0.06707	19.12	0.000
year	0.131927	0.009114	14.48	0.000

S = 0.108982   R-Sq = 95.4%   R-Sq(adj) = 95.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	2.4889	2.4889	209.55	0.000
Residual Error	10	0.1188	0.0119		
Total	11	2.6076			

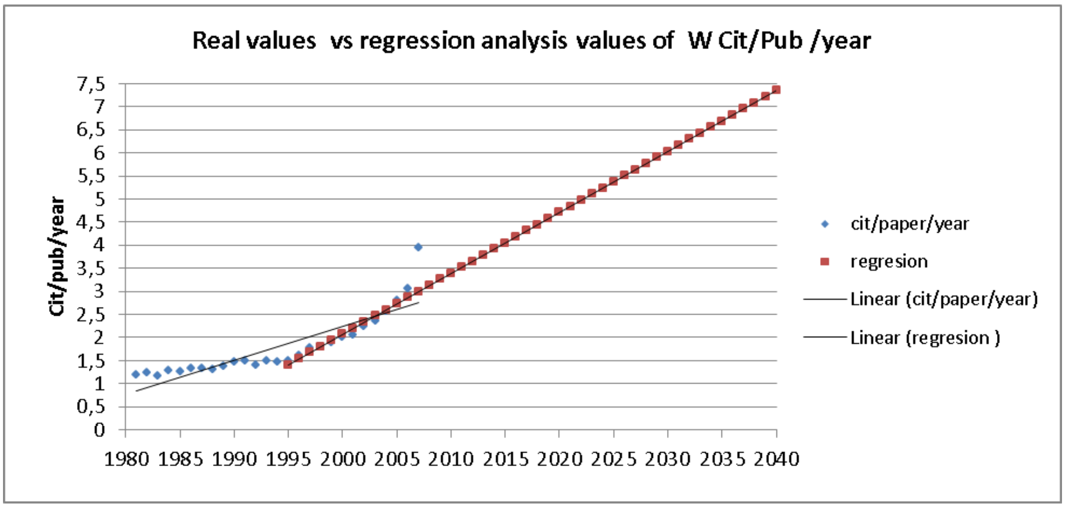

Figure A.9. Real Values vs Regression analysis values of W Cit/pub/year

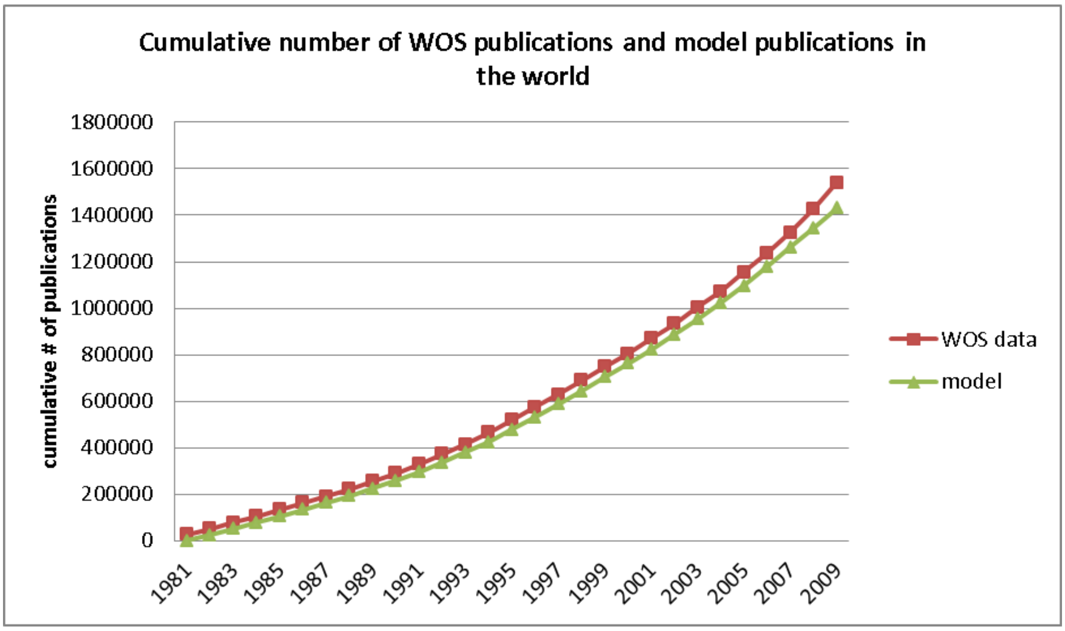

Figure A.10. Cumulative number of WOS publications and model publications in the world

Table A.2. Regression Analysis: WOS publications versus year

Regression Analysis: WOS publications versus years

The regression equation is
WOS publications = 47764 + 2574 year

Predictor	Coef	SE Coef	T	P
Constant	47764	2597	18.39	0.000
year	2574.2	352.8	7.30	0.000

S = 4219.02 R-Sq = 84.2% R-Sq(adj) = 82.6%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	947600089	947600089	53.24	0.000
Residual Error	10	178001562	17800156		
Total	11	1125601650			

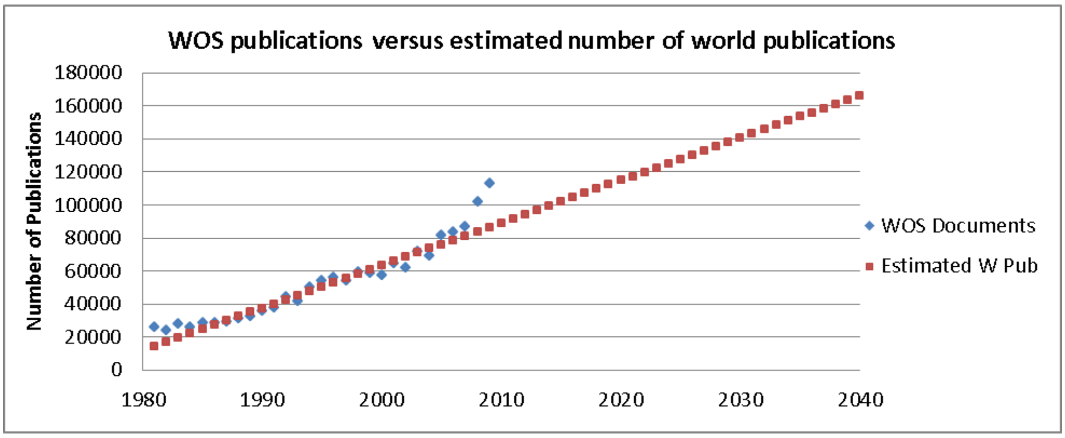

Figure A.11. WOS publications versus estimated number of world publications

Table A.3. Quality boundaries for publications for each year.

year		**W citations per paper**	**A quality boundary (avg*2)**	**C quality boundary (avg/2)**
1981	first 8 years	5,6	11,2	2,8
1982	first 8 years	5,73	11,46	2,87
1983	first 8 years	5,88	11,76	2,94
1984	first 8 years	5,99	11,98	3
1985	first 8 years	6,09	12,18	3,05
1986	first 8 years	6,19	12,38	3,1
1987	first 8 years	6,29	12,58	3,15
1988	first 8 years	6,41	12,82	3,21
1989	first 8 years	6,56	13,12	3,28
1990	first 8 years	6,74	13,48	3,37
1991	first 8 years	6,98	13,96	3,49
1992	first 8 years	7,28	14,56	3,64
1993	first 8 years	7,63	15,26	3,82
1994	first 8 years	8,02	16,04	4,01
1995	first 8 years	8,47	16,94	4,24
1996	first 8 years	8,95	17,9	4,48
1997	first 8 years	9,5	19	4,75
1998	first 8 years	10,15	20,3	5,08
1999	first 8 years	10,86	21,72	5,43
2000	first 8 years	11,54	23,08	5,77
2001	first 9 years	13,81	27,62	6,91
2002	first 8 years	12,85	25,7	6,43
2003	first 7 years	11,63	23,26	5,82
2004	first 6 years	10,1	20,2	5,05
2005	first 5 years	8,28	16,56	4,14
2006	first 4 years	6,24	12,48	3,12

Table A.4. Bogaziçi University Engineering Faculty Publications with quality categorization.

Bogaziçi Univ Engineering Faculty Publications (data from Web Of Science)														
Year	**Faculty**	**Publish Rate**				**Publication Percentage**			**Publication percentage*required time / Faculty**			**Research Time Percentage**		
		A	**B**	**C**	**Total**	**A**	**B**	**C**	**A**	**B**	**C**	**fract A**	**fract B**	**fract C**
1981	98	1	0	3	4	0,25	0	0,75	0,0020	0	0,0015	0,57	0	0,43
1982	99	0	0	5	5	0	0	1	0	0	0,0020	0	0	1
1983	100	1	0	3	4	0,25	0	0,75	0,0020	0	0,0015	0,57	0	0,43
1984	101	0	2	2	4	0	0,50	0,50	0	0,0020	0,0010	0	0,67	0,33
1985	102	0	3	4	7	0	0,43	0,57	0	0,0017	0,0011	0	0,60	0,40
1986	103	0	7	5	12	0	0,58	0,42	0	0,0023	0,0008	0	0,74	0,26
1987	104	2	7	1	10	0,20	0,70	0,10	0,0015	0,0027	0,0002	0,35	0,61	0,04
1988	105	1	7	4	12	0,08	0,58	0,33	0,0006	0,0022	0,0006	0,18	0,64	0,18
1989	106	5	9	3	17	0,29	0,53	0,18	0,0022	0,0020	0,0003	0,49	0,44	0,07
1990	107	3	6	6	15	0,20	0,40	0,40	0,0015	0,0015	0,0007	0,40	0,40	0,20
1991	108	4	4	7	15	0,27	0,27	0,47	0,0020	0,0010	0,0009	0,52	0,26	0,23
1992	109	3	14	16	33	0,09	0,42	0,48	0,0007	0,0016	0,0009	0,21	0,50	0,29
1993	110	2	8	11	21	0,10	0,38	0,52	0,0007	0,0014	0,0010	0,23	0,46	0,31

Table A.4 : Bogaziçi University Engineering Faculty Publications with quality categorization (continued)

Bogaziçi Univ Engineering Faculty Publications (data from Web Of Science)

Year	**Faculty**	**Publish Rate**				**Publication Percentage**			**Publication percentage*required time / Faculty**			**Research Time Percentage**		
		A	**B**	**C**	**Total**	**A**	**B**	**C**	**A**	**B**	**C**	**fract A**	**fract B**	**fract C**
1994	111	5	16	15	36	0,14	0,44	0,42	0,0010	0,0016	0,0008	0,30	0,48	0,22
1995	112	3	13	20	36	0,08	0,36	0,56	0,0006	0,0013	0,0010	0,21	0,45	0,34
1996	113	5	24	15	44	0,11	0,55	0,34	0,0008	0,0019	0,0006	0,24	0,58	0,18
1997	115	10	19	22	51	0,20	0,37	0,43	0,0014	0,0013	0,0008	0,40	0,38	0,22
1998	116	5	26	25	56	0,09	0,46	0,45	0,0006	0,0016	0,0008	0,21	0,54	0,26
1999	117	9	26	20	55	0,16	0,47	0,36	0,0011	0,0016	0,0006	0,33	0,48	0,19
2000	118	6	20	32	58	0,10	0,34	0,55	0,0007	0,0012	0,0009	0,25	0,42	0,33
2001	119	8	29	27	64	0,13	0,45	0,42	0,0008	0,0015	0,0007	0,27	0,50	0,23
2002	120	8	30	29	67	0,12	0,45	0,43	0,0008	0,0015	0,0007	0,26	0,50	0,24
2003	122	5	19	39	63	0,08	0,30	0,62	0,0005	0,0010	0,0010	0,21	0,39	0,40
2004	123	15	31	26	72	0,21	0,43	0,36	0,0014	0,0014	0,0006	0,41	0,42	0,18
2005	124	11	41	25	77	0,14	0,53	0,32	0,0009	0,0017	0,0005	0,29	0,54	0,17
2006	125	19	55	31	105	0,18	0,52	0,30	0,0012	0,0017	0,0005	0,35	0,51	0,14

Table A.5. cit/p/y parameters for BU EF publications found with simplified publication-citation model

year	**cit/p/y A**	**cit/p/y B**	**cit/p/y C**
1981	1,4		0,02
1982			0,03
1983	1,45		0,2
1984		0,5	0,04
1985		0,8	0,48
1986		0,72	0,17
1987	3	0,88	0
1988	1,9	0,82	0,09
1989	2,74	1,07	0,27
1990	2,47	0,62	0,36
1991	3,1	1,12	0,16
1992	2,9	0,975	0,255
1993	3,65	1,23	0,245
1994	4,15	1,17	0,33
1995	6,42	1,33	0,23
1996	4,9	1,67	0,255
1997	12,45	1,85	0,305
1998	8,06	1,95	0,405
1999	7,9	1,91	0,3
2000	9,05	2,02	0,425
2001	14,6	2,14	0,39
2002	9,8	2,1	0,385
2003	9,2	2,3	0,52
2004	10,35	2,39	0,47
2005	7,52	2,33	0,48
2006	9,1	2,3	0,43

Table A.6. The values used in calculation of Ext cit /p/y and Int cit /p/y parameters for year 1995.

	A	**B**	**C**
Publications	9	39	60
Total citations	489	447	117
Average citations per paper	54	11,5	2
Average internal citations per paper	8	3,4	1
Average external citations per paper	46	8,6	1
Resulting int cit / p / y	0,49	0,21	0,06
Resulting ext cit / p / y	5,45	1	0,12

Table A.7. Conditional self-citation means for papers published in 1992 with at most 50 foreign citations for 1 to 10 year citation windows. (Glanzel, 2004)

k	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**T(k)**
0	0.10	0.29	0.39	0.44	0.47	0.48	0.49	0.49	0.49	0.48	*0.47*
1	0.35	0.62	0.79	0.89	0.95	0.98	1.00	1.01	1.02	1.02	*1.13*
2	0.57	0.90	1.10	1.20	1.27	1.31	1.35	1.35	1.37	1.38	*1.56*
3	0.80	1.15	1.37	1.48	1.55	1.60	1.64	1.65	1.64	1.66	*1.91*
4	0.93	1.36	1.60	1.74	1.82	1.85	1.88	1.90	1.90	1.91	*2.22*
5	1.10	1.58	1.83	1.97	2.05	2.09	2.10	2.14	2.16	2.14	*2.49*
6	1.23	1.70	2.04	2.22	2.26	2.30	2.33	2.35	2.37	2.36	*2.74*
7	1.39	1.92	2.25	2.39	2.48	2.53	2.57	2.54	2.54	2.56	*2.97*
8	1.34	2.05	2.34	2.56	2.69	2.74	2.73	2.78	2.77	2.77	*3.19*
9	1.84	2.17	2.56	2.76	2.92	2.89	2.95	2.95	2.94	2.92	*3.40*
10	1.76	2.41	2.77	2.99	3.06	3.17	3.15	3.15	3.16	3.10	*3.60*
11	2.01	2.51	2.79	3.12	3.22	3.34	3.31	3.29	3.28	3.33	*3.79*
12	1.64	2.60	3.02	3.25	3.37	3.44	3.48	3.48	3.48	3.49	*3.97*
13	2.19	2.52	3.24	3.40	3.57	3.60	3.67	3.61	3.67	3.63	*4.14*
14	2.52	2.93	3.38	3.68	3.62	3.72	3.87	3.86	3.76	3.73	*4.31*
15	1.63	2.96	3.46	3.73	3.97	3.93	4.00	4.06	3.90	3.92	*4.48*
16	1.91	3.13	3.71	3.88	4.19	4.20	4.16	4.07	4.14	4.13	*4.63*
17	2.78	2.98	3.74	4.07	4.20	4.31	4.27	4.36	4.33	4.25	*4.79*
18	2.60	3.10	3.87	4.01	4.29	4.42	4.44	4.51	4.54	4.56	*4.94*
19	2.10	3.35	3.83	4.42	4.33	4.54	4.68	4.67	4.61	4.62	*5.09*
20	1.86	3.38	3.90	4.54	4.66	4.64	4.72	4.77	4.79	4.74	*5.23*
21	2.25	3.67	4.28	4.42	4.85	4.88	4.86	4.89	4.88	4.93	*5.37*
22	3.38	3.38	4.44	4.68	4.65	4.90	5.11	5.00	5.01	5.22	*5.51*
23	1.50	3.68	4.31	4.85	5.05	5.14	5.17	5.16	5.26	4.90	*5.64*
24	2.60	4.15	4.38	4.91	5.25	5.21	5.25	5.32	5.34	5.34	*5.78*
25	6.17	3.91	4.68	5.03	5.16	5.46	5.53	5.45	5.43	5.46	*5.91*
26	4.83	3.65	4.52	5.24	5.59	5.59	5.61	5.66	5.65	5.57	*6.03*
27	4.00	3.90	4.98	5.48	5.44	5.56	5.72	5.63	5.77	5.85	*6.16*
28	–	3.40	4.57	5.27	5.38	5.99	5.74	6.02	5.81	5.78	*6.28*
29	3.33	4.23	4.88	5.49	5.90	5.75	5.88	6.09	6.11	6.11	*6.40*
30	5.33	4.69	5.03	5.42	5.85	6.04	5.99	6.08	6.10	6.08	*6.52*
31	3.67	4.59	4.85	5.76	6.07	6.01	6.31	5.99	5.87	6.24	*6.64*
32	0.00	4.68	5.39	5.99	5.97	6.30	6.25	6.23	6.47	6.14	*6.76*
33	4.67	4.16	5.36	6.15	5.93	6.46	6.46	6.70	6.55	6.22	*6.87*
34	1.00	4.92	5.36	5.68	6.58	6.55	6.63	6.53	6.45	6.61	*6.98*
35	2.67	5.56	5.60	5.93	6.88	6.54	6.89	7.00	6.68	6.89	*7.09*
36	2.50	4.21	5.18	6.15	6.82	6.55	6.89	6.76	6.84	6.96	*7.20*
37	2.00	5.02	5.73	6.11	6.72	6.78	6.82	6.89	7.06	6.71	*7.31*
38	–	7.00	5.32	6.62	6.67	6.67	6.65	7.04	6.67	7.19	*7.42*
39	7.50	4.75	5.45	6.76	6.61	6.85	7.22	6.82	7.24	7.07	*7.53*
40	1.00	5.45	6.18	6.18	6.98	7.12	7.27	7.34	7.35	7.19	*7.63*
41	2.50	4.93	6.83	6.59	6.90	7.50	7.03	7.44	7.71	7.32	*7.74*
42	10.00	4.91	6.67	7.00	6.65	7.58	7.30	7.47	7.62	7.37	*7.84*
43	–	4.71	5.59	6.77	7.35	7.35	7.44	7.82	7.53	7.62	*7.94*
44	–	6.27	6.52	6.51	6.85	7.60	7.55	7.50	7.92	7.59	*8.04*
45	–	4.72	6.69	7.35	7.39	7.62	8.21	7.75	7.31	8.31	*8.14*
46	3.00	5.55	6.29	7.00	7.90	8.42	8.06	8.23	8.24	8.14	*8.24*
47	3.00	4.64	6.65	7.50	8.17	7.69	7.78	7.78	8.06	7.66	*8.34*
48	–	4.93	6.53	7.22	7.33	7.63	7.88	8.19	8.13	7.87	*8.43*
49	–	4.68	6.89	7.60	7.41	7.74	8.70	8.46	8.52	8.61	*8.53*
50	1.00	5.07	6.98	7.19	7.83	8.19	8.43	8.43	8.18	8.32	*8.62*

Table A.8. Regression analysis for projecting the number of faculty into the future

Regression Analysis: C4 versus C1

The regression equation is
Faculty= 111 + 1.17 Year

Predictor	Coef	SE Coef	T	P
Constant	110.955	1.531	72.47	0.000
Year	1.1695	0.1684	6.95	0.000

S = 2.81769 R-Sq = 78.8% R-Sq(adj) = 77.1%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	382.94	382.94	48.23	0.000
Residual Error	13	103.21	7.94		
Total	14	486.15			

Unusual Observations

Obs	Year	Faculty	Fit	SE Fit	Residual	St Resid
2	2.0	119.301	113.294	1.245	6.007	2.38R
7	7.0	113.087	119.141	0.747	-6.054	-2.23R

R denotes an observation with a large standardized residual.

Appendix B: EXTREME CONDITION RUNS

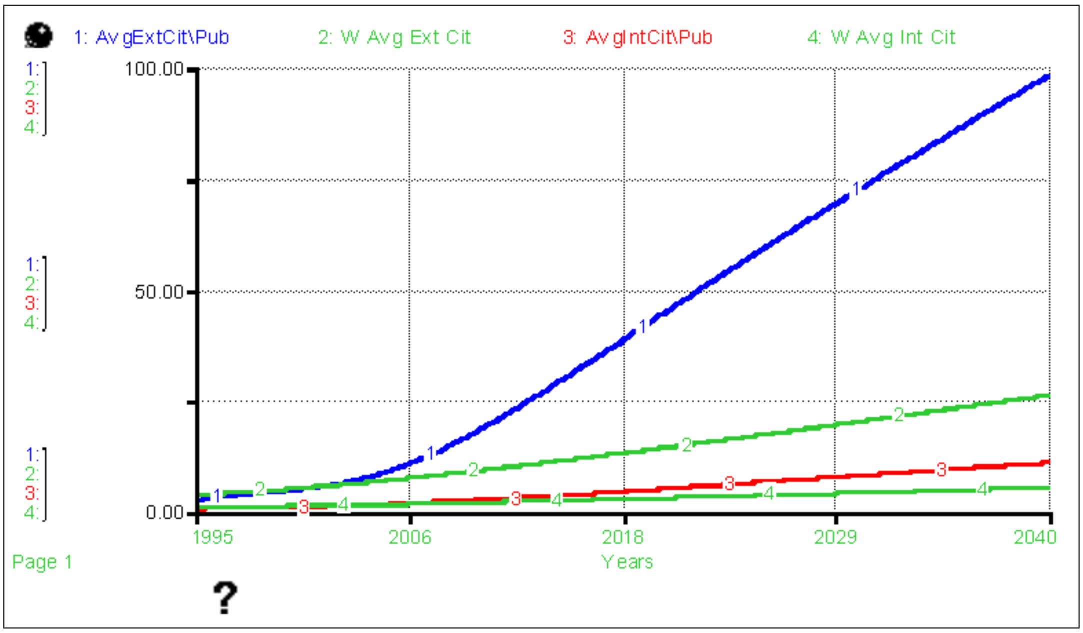

Figure B.1. avg cit / p / y values in Extreme condition 1 – perfect faculty members

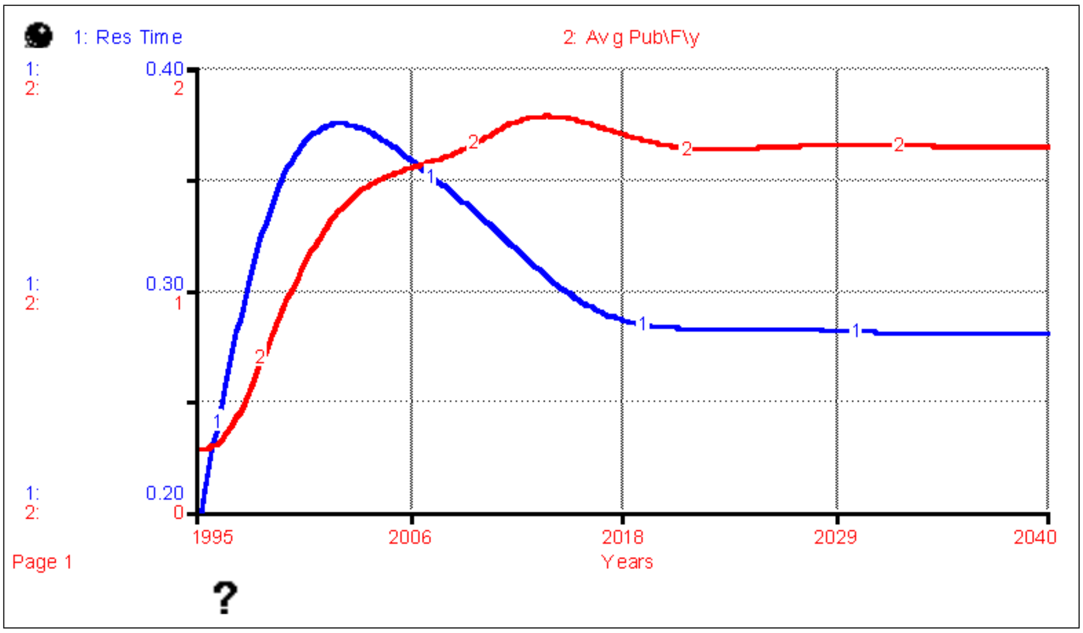

Figure B.2. Avg Pub /f/y and Research Time in Extreme condition 1 – perfect faculty members

Figure B.3. Research Time allocation in Extreme condition 1 – perfect faculty members

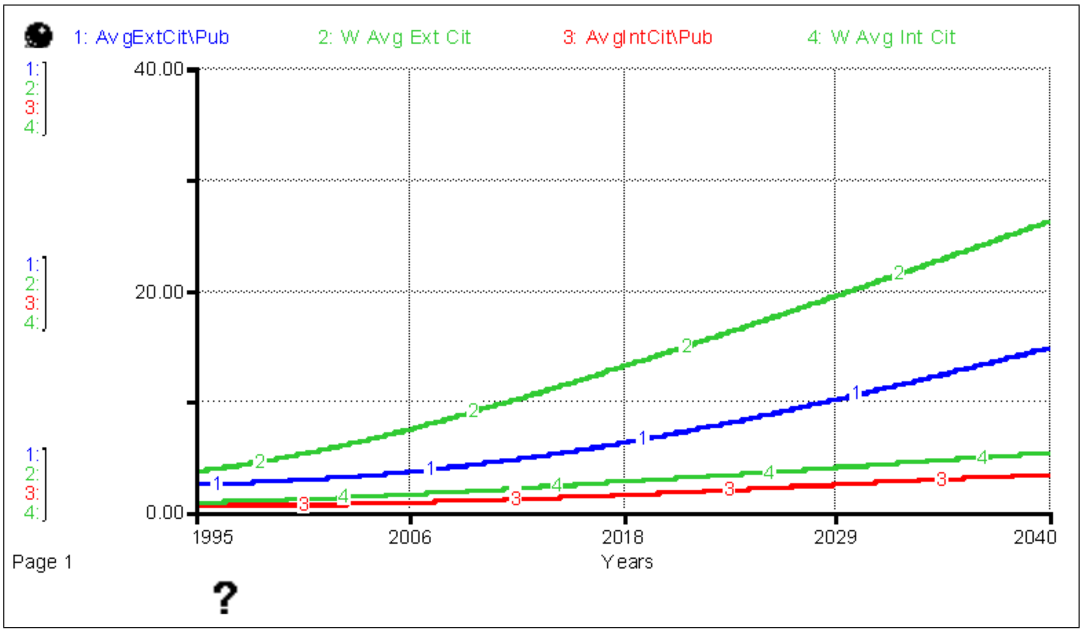

Figure B.4. Avg cit / pub values in Extreme condition 2 – Skill level is set 5

Figure B.5. Research Time allocation in Extreme condition 2 – Skill level is set 5

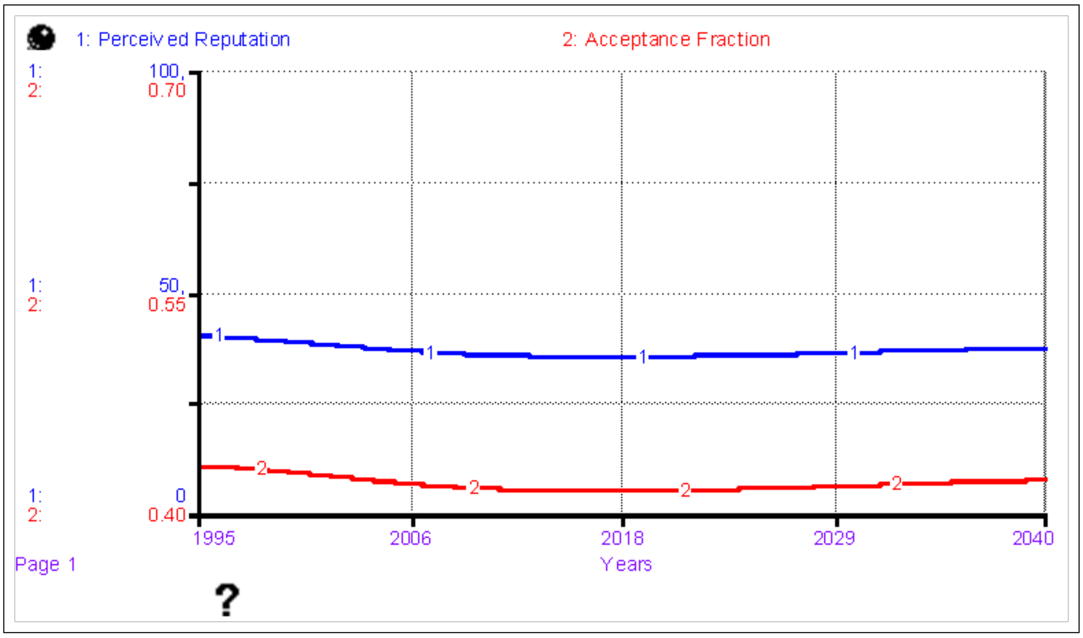

Figure B.6. Reputation and Acceptance Fraction in Extreme condition 2 – Skill level is set 5

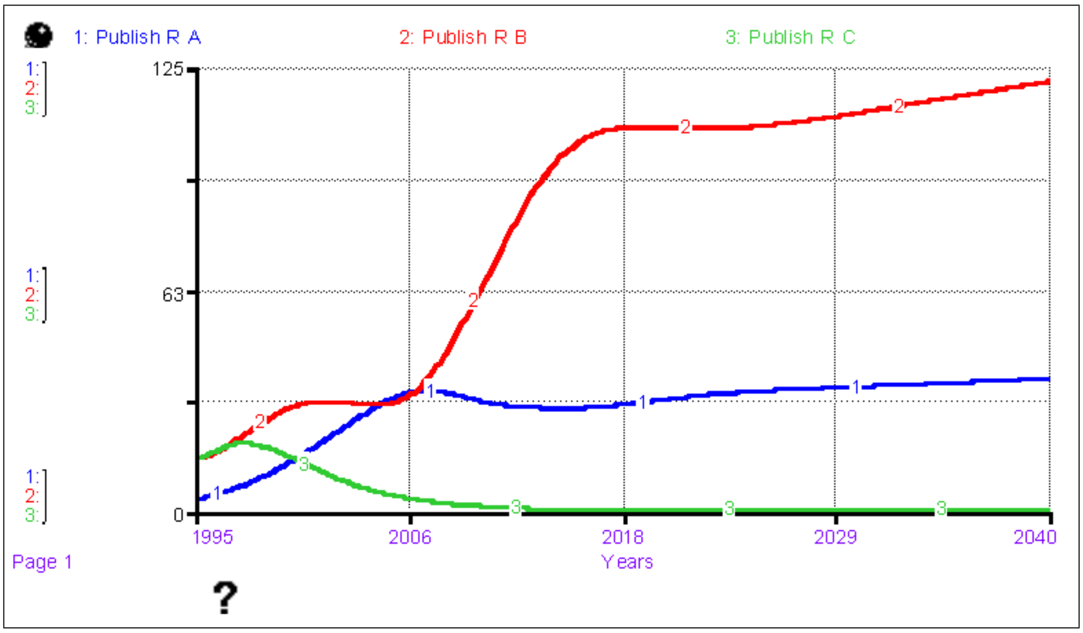

Figure B.7. Publish Rate in Extreme Condition 5 - Normal fract A is set 100

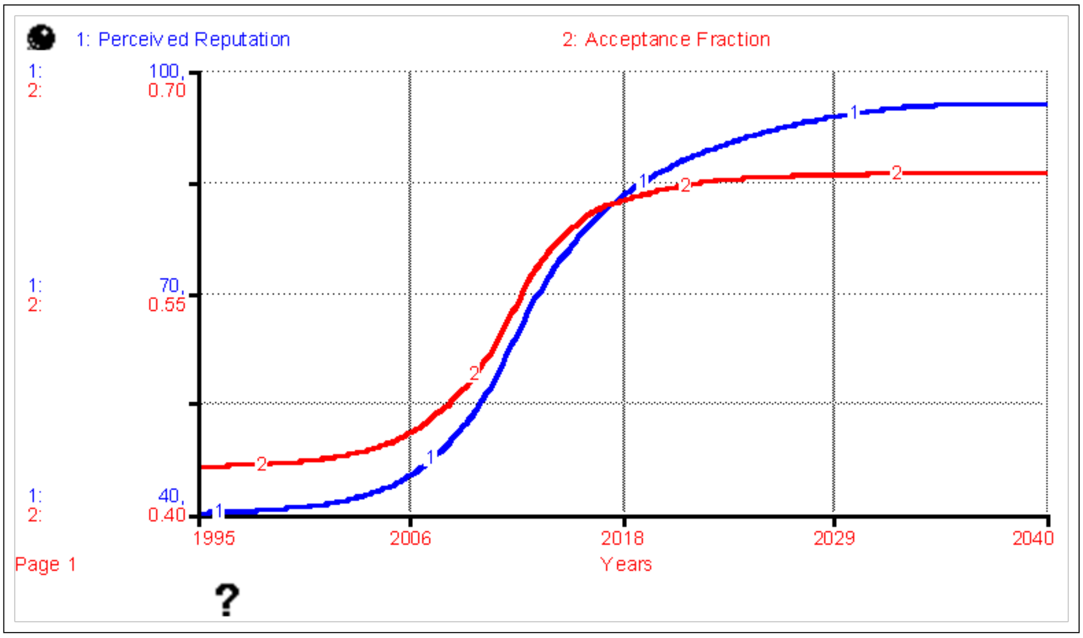

Figure B.8. Reputation and Acceptance Fraction in Extreme Condition 5 - Normal fract A is set 100

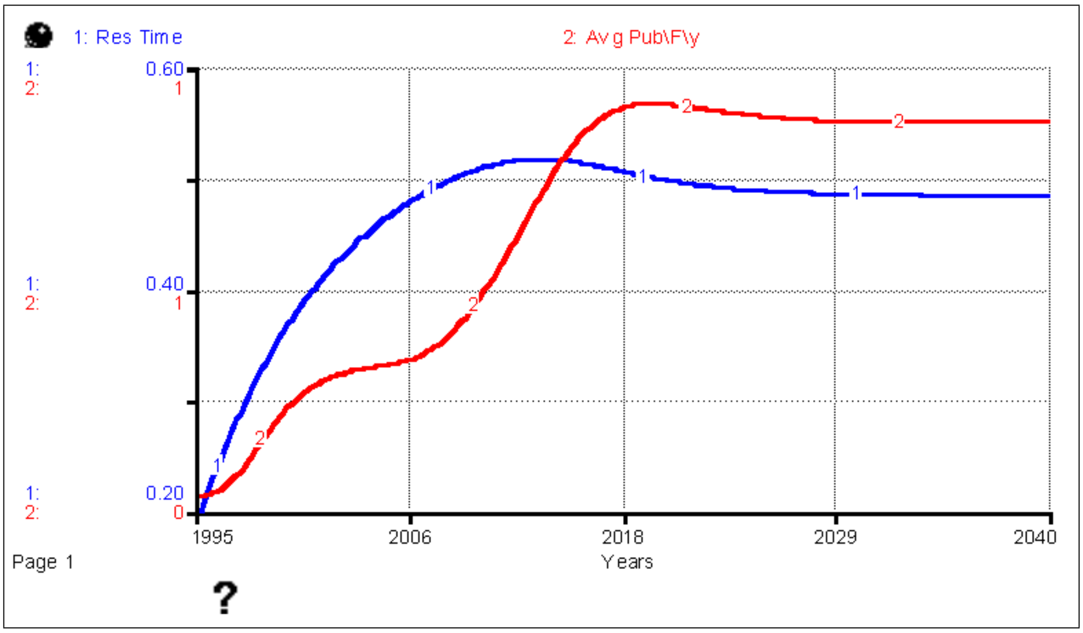

Figure B.9. Research Time and Avg Pub/f/y in Extreme Condition 5 - Normal fract A is set 100

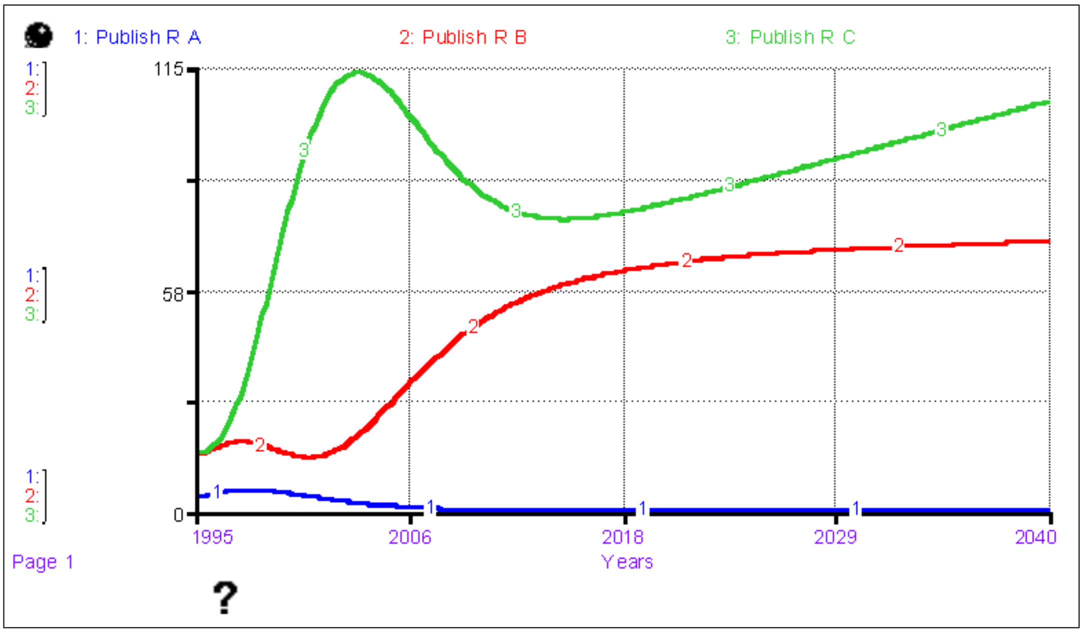

Figure B.10. Publish Rate in Extreme Condition 6 - Normal fract C is set 100

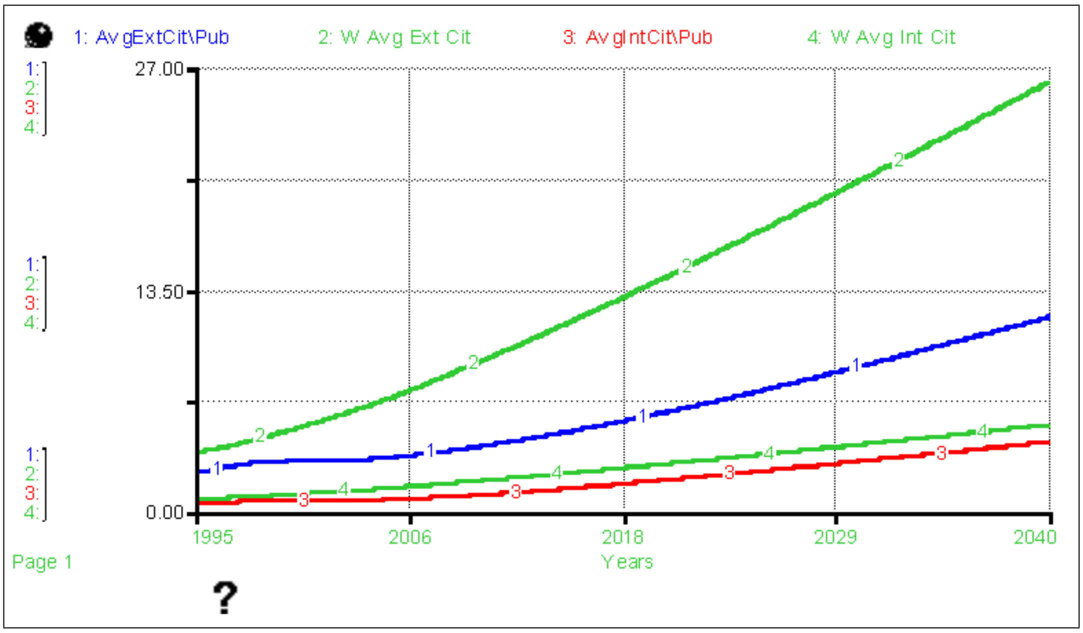

Figure B.11. avg cit/pub values in Extreme Condition 6 - Normal fract C is set 100

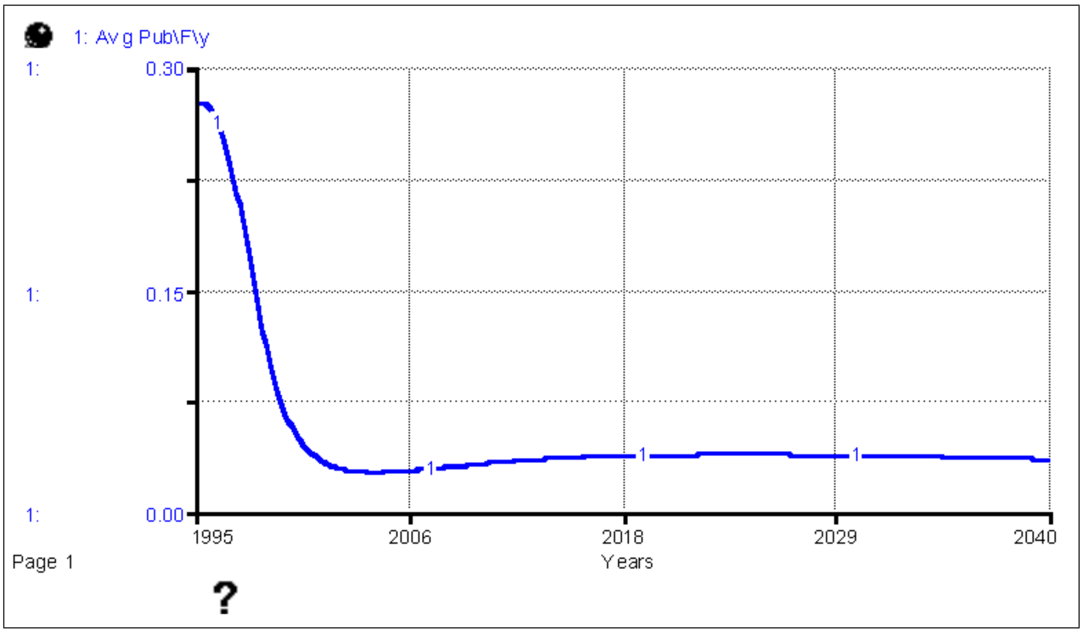

Figure B.12. avg pub /f/y in Extreme Condition 7 – Research Time is set 0.01

Figure B.13. Research Time allocation in Extreme Condition 7 – Research Time is set 0.01

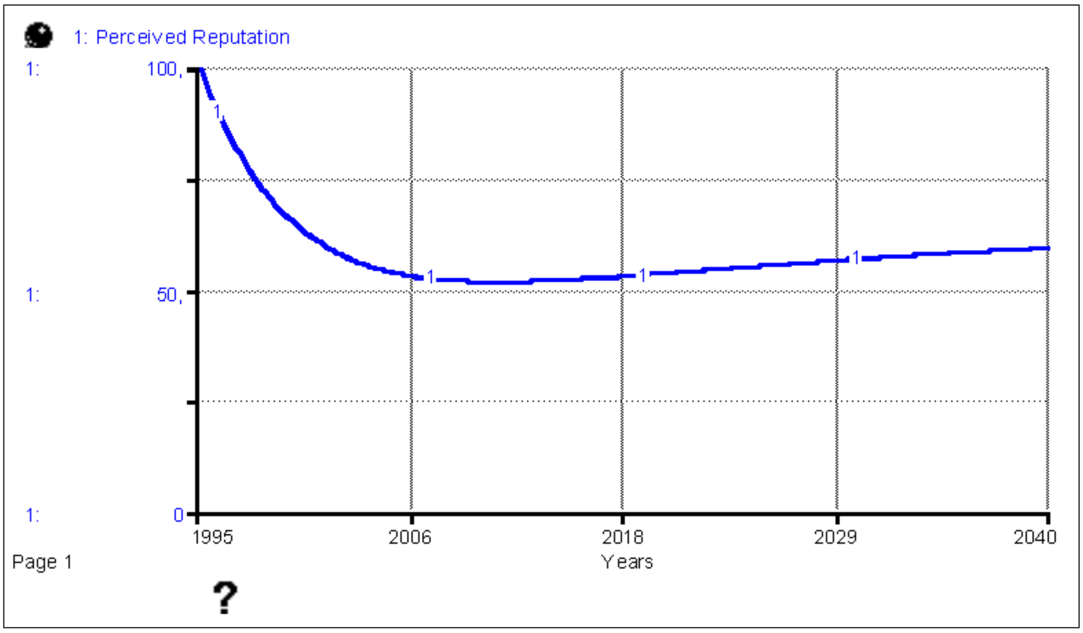

Figure B.14. Reputation in Extreme Condition 9 – Initial Reputation is set 100

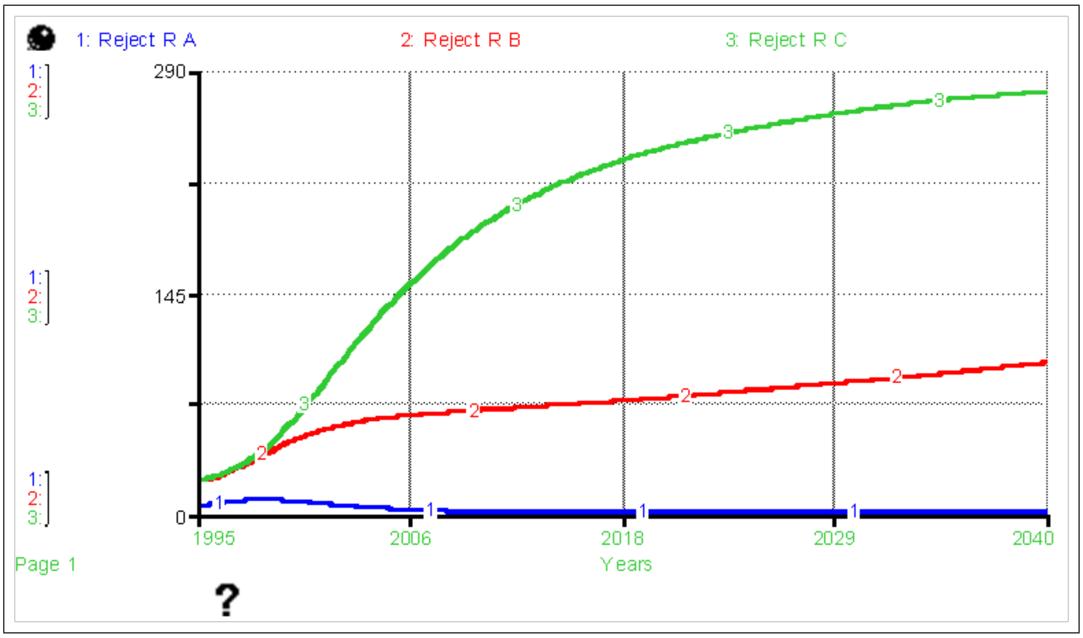

Figure B.15. Reject Rates in Extreme Condition 10 – Acceptance Fraction is set 0.01

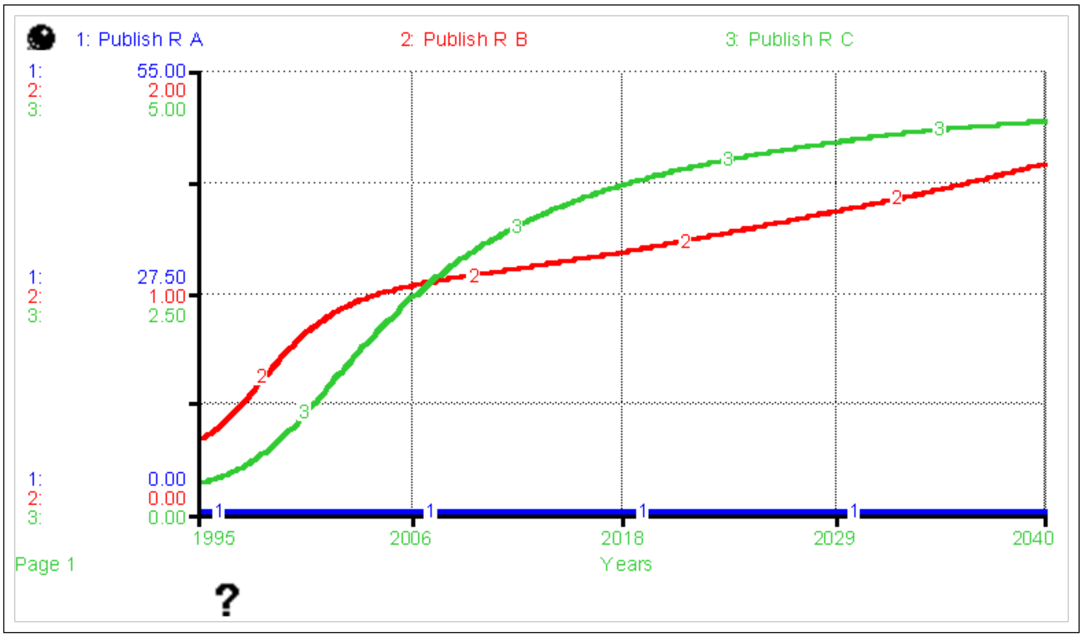

Figure B.16. Publish Rates in Extreme Condition 10 – Acceptance Fraction is set 0.01

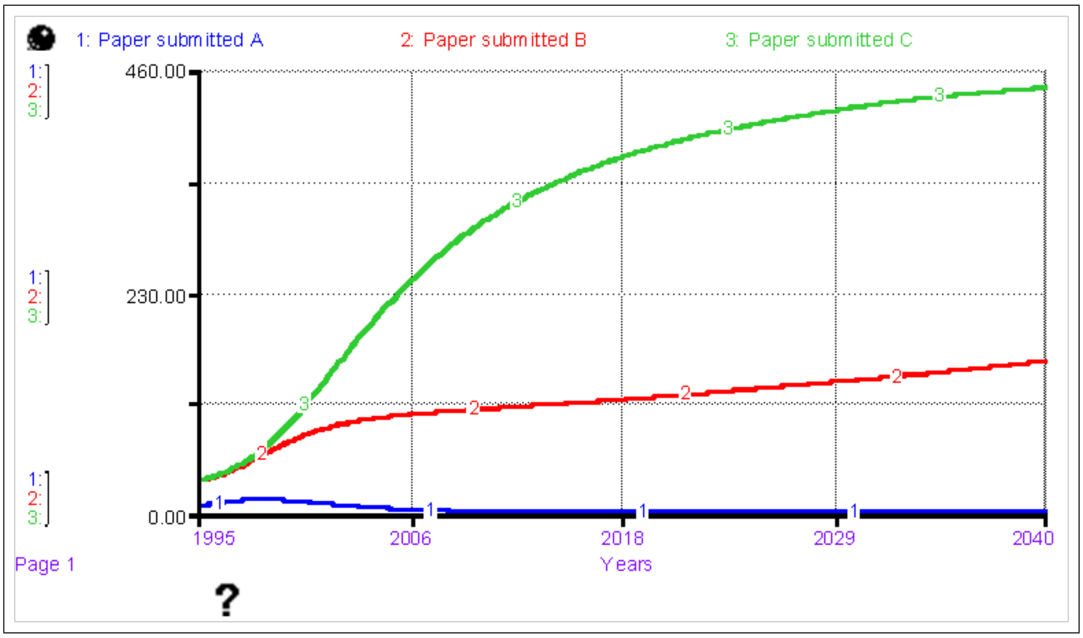

Figure B.17. Paper Submitted Stocks in Extreme Condition 10 – Acceptance Fraction is set 0.01

Appendix C: SIMULATION MODEL

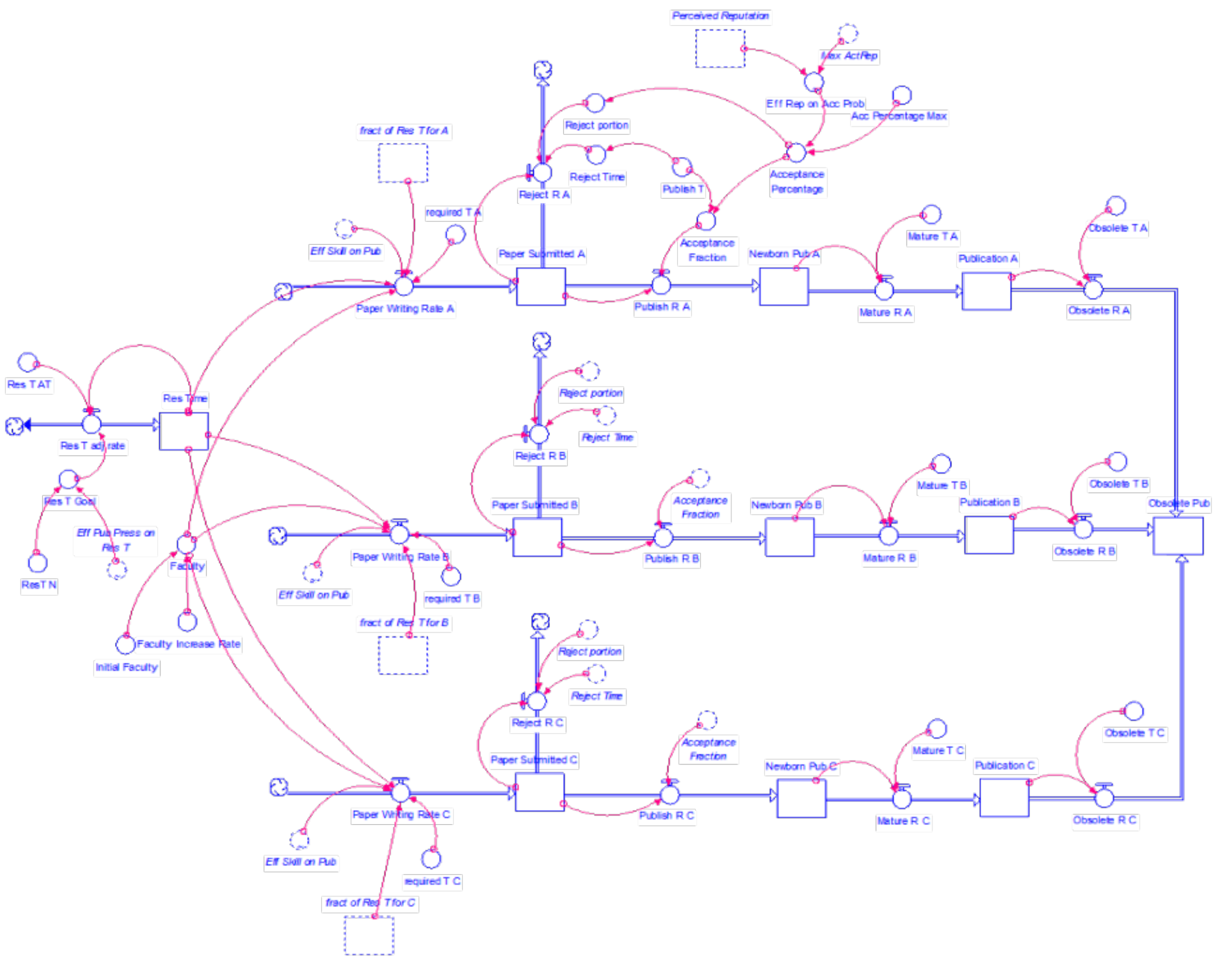

Figure C.1. Simulation model part 1

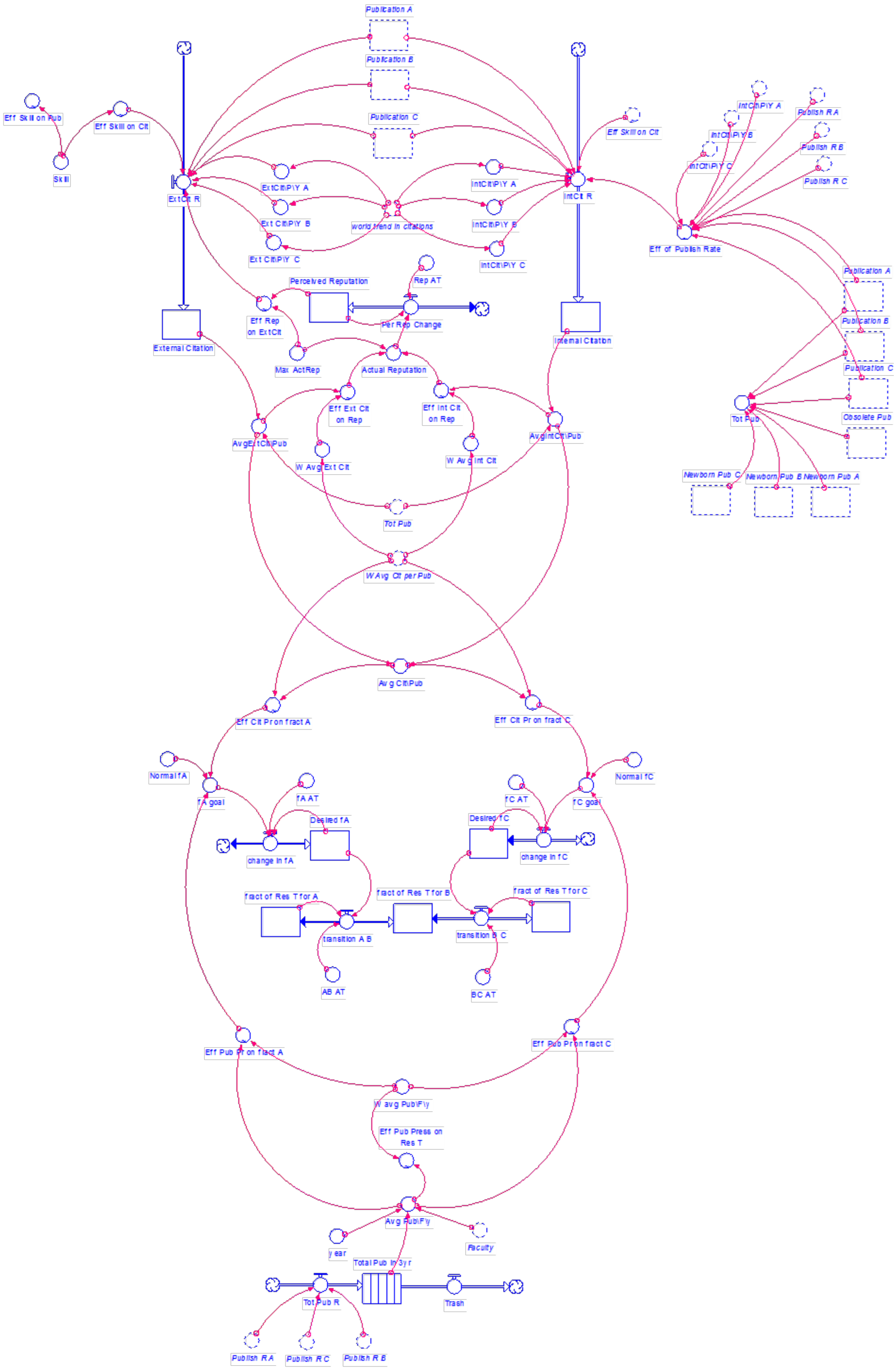

Figure C.2. Simulation model part 2

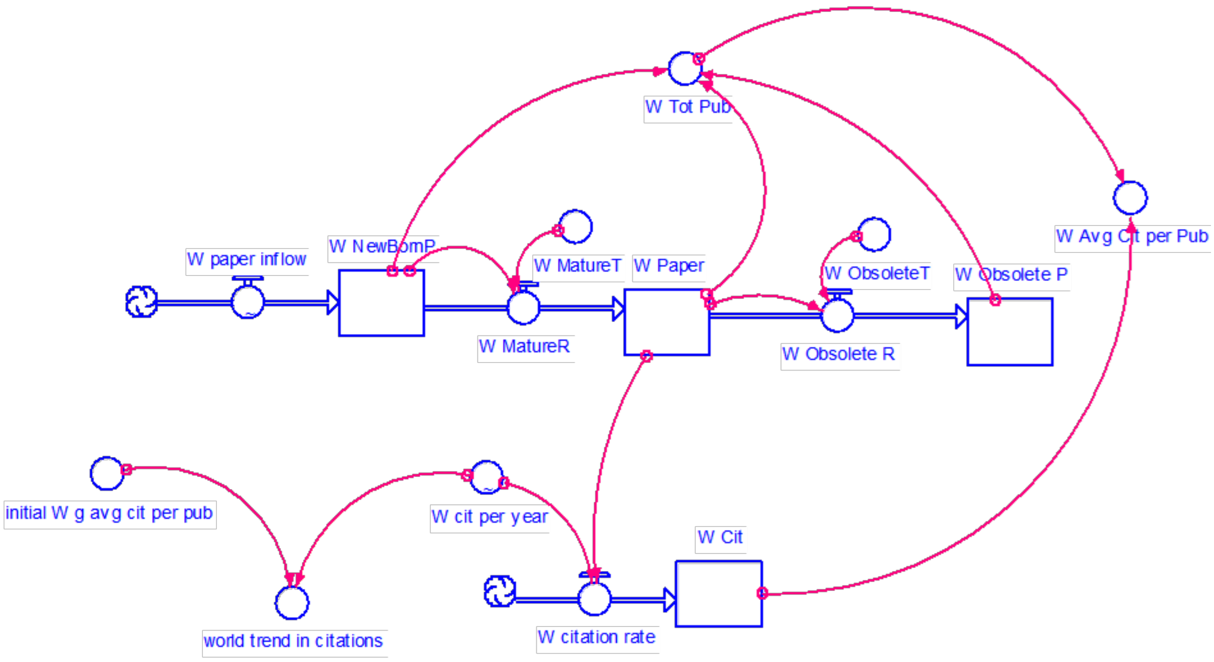

Figure C.3. Simulation model part 3

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