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Optimal Scope and Length of Software Patents - A Simulative Approach

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A Simulative Approach

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Abstract

Traditionally, only technical inventions such as light bulbs or pharmaceuticals were protected by patents. Nowadays software patents are a widely discussed topic in the U.S. and in Europe because of their proposed impact on national innovation rates. Based on an analysis of the determinants of successfully developing software, we use a bipartite probability model to compare a deregulated market without patents to a market using a patent system. Applying computer-based simulations, we analyze different scenarios to test the impact of different patent duration and width on the innovation behavior of the software market. We can show that strong patent protection is globally efficient only in markets with a relatively low profit potential.

1. Introduction

Traditionally, patent protection was awarded only to technical inventions, such as light bulbs, shavers, or pharmaceuticals. After computer programming became viable, and protection of computer programs became desirable most countries decided that software was too abstract or intangible to be patentable, and copyright became the dominant form of protection. In the last years firms were going to demand patents on *software-related inventions, which drove* an intense public and academic discussion regarding the use of patent systems to protect software.

Software consists of functional as well as expressive attributes. Functional attributes describe special instructions and expressive attributes their representation [7]. This hybrid structure made it difficult for patent officials to assess the technical character of inventions, which is a prerequisite for patenting inventions. Another problem is the lack of qualified patent inspectors and the associated difficulty to assess the novelty. This has resulted in quite a number of patents being granted for inventions considered to be obvious by experts in the field.

The goal of this paper is to answer these questions:

1. How do scenarios with and without patent system differ in terms of the endemic propensity to monopolize?

2. In which scenario can we expect a higher level of innovation?

After an overview of specific characteristics of the software market (section 2.1) a survey of economic and legal patent issues (section 2.2) is given. Based on this, an economic simulation model incorporating individual patent incentives and their implications on (aggregate) system behavior is recapitulated from an earlier paper (section 3). Section 4 presents the simulation results as well as the arising conclusions. Section 5 gives a short summarization of the paper and proposes future research.

2. Literature Review

2.1 Special Issues of the Software Market

Market topology: The market for software products is embedded into the IT market, which is part of the Information and Communication Technology (ICT) market shown in Figure 1.

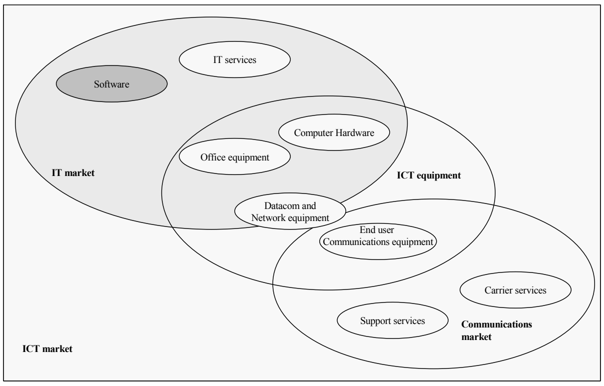

Figure 1: Complexity and different submarkets of the ICT market

Beside a high momentum in technical innovations and strong competitiveness in the ICT market, leading to constantly shorter product cycles and even higher pressure towards innovativeness, one can also identify paradigm shifts that lead to fundamental changes of business rules in general [5]. The wide application of ICT has lead to a rapid decline in prices and costs in the computing and telecommunications sector with positive repercussions for a variety of other products, like aircrafts, automobiles and scientific instruments. Table 1 shows the forecasted revenues in different regional software markets [12].

Cost structure: It is relatively costly to produce the first copy of a software product while the costs of additional copies are very low (e.g. CD-ROM) or even negligible (e.g. if distributed via download from the Internet). From an economic perspective this means high fixed costs and very low marginal costs leading to substantial economies of scale [29]. Compared to the chemical market with fixed costs for developing one product amounting to € 300 million [6], the fixed costs are low. Since software is immaterial, the distribution costs also are significantly lower than for physical goods.

Instant scalability: Closely related to the cost structure is the phenomenon of instant scalability in software markets. Since it is very easy to reproduce and distribute copies of software, suppliers can respond very quickly to an increase in demand. Therefore, once a software product is recognized as superior, the particular vendor might be able to gain a significant market share in a short period of time [25].

Pricing: Cost structure and instant scalability influence pricing strategies in software markets. Of course it does not make sense to apply marginal-cost-based pricing if the costs of reproduction are close to zero. Pricing is more likely to be determined by consumer value, leading to *differential pricing* [29]. Because of the importance of the installed base due to positive network effects, dynamic pricing (and in particular *penetration pricing*) is one of the most important strategies in modern software markets.

Positive network effects: It is common in many markets that a consumer's buying decision influences the others´ decisions. Interdependencies such as the *bandwagon, snob,* and *Veblen effect* are broadly discussed in the economic literature (e.g. [8]). Beside these general effects, which apply to all consumer decisions, software markets are determined by *positive network effects*, the so-called *demand-sided economies of scale*, deriving from the need for product compatibility. This means that the willingness to adopt a product innovation correlates positively with the number of existing adopters. These effects mainly originate from two different areas, the need for compatible products to exchange data or information (*direct network effects*) and the need for complementary products and services (*indirect network effects*) [11] [14] [23].

Table 1: Total Revenue of the ICT market (Million €) [12]

2003	Western Europe	Eastern Europe	USA	Japan	Rest of World	World
ICT equipment	211,544	12,236	208,721	119,759	216,815	769,077
Software	**81,856**	**1,845**	**135,606**	**22,813**	**45,070**	**287,189**
IT services	158,773	2,876	262,536	73,276	85,203	582,664
Carrier services	278,381	19,244	293,541	111,801	338,207	1,041,173
Total	730,554	36,201	900,404	327,649	685,295	2,0680,103

Tippiness: Supply-sided economies of scale, instant scalability, and positive network effects can result in a specific dynamic structural change in software markets referred to as *tippiness*. If the diffusion of a certain software product gains sufficient momentum the market might tip meaning that a particular product takes over the entire market in a short time. The phenomenon is analyzed analytically in [2] and empirically in [25].

Start-up problem and critical mass: Due to the existence of network effects, early technology adopters bear the risk of buying a product which might not succeed in gaining the expected market share. This can lead to *excess inertia* even if the product is seen as superior [2]. Related to the start-up problem is the *critical mass*, being the threshold number of users needed to overcome the start-up problem. Reaching this point in the diffusion process might then again result in rapid acceleration and in tipping of the market.

Propensity to monopolize: Network effect literature states that multiple, incompatible technologies can only rarely coexist in markets with network effects, and that instant scalability results in an additional tendency to monopolize. Empirical observations show monopolistic structures in some of the modern software markets like the market for office suites, word processors, or spreadsheets [25].

Utilization and availability of open code: Open code is one of the most important external factors for software development (up to 20%) [15]. The strongest usage emanates from independent developers, but recently the reuse of open source software by medium-size and large companies has increased as well [15]. Open source has a generic character, i.e. in many cases it is functional input which makes software development more effective. There is no significant argument for utilizing open source, but a relatively well balanced set of motives (e.g. adaptability, state-of-the-art, costs and quality). Disclosure of code is used mostly as strategy to diffuse information about one's own performance.

2.2 Special Issues of Patents

2.2.1 Legal Perspective

Until the US Supreme Court's decision *Diamond vs. Diehr* in 1981, patent protection for software was almost non-existent. In this instance, the Court ruled that a computerized process for curing rubber was patentable even though the process involved an algorithm which by itself was not patentable [27]. The distinction was that the algorithm was applied to a process, as opposed to attempting to patent the algorithm [27]. Computer programs are patentable in the USA today. It is even possible to patent business methods. Basically, the requirements for patentable items (inventions) are ruled in part II, chapter 10 of the U.S: Patent Act [31]: "*Whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent therefore, subject* *to the conditions and requirements of this title*" [31, § 101]. The criteria for granting a patent are:

The person is the inventor [31, § 102], the invention is the proper subject matter for a patent: machines, articles of manufacture, compositions of matter, and processes [31, § 101], and the invention is "useful", "new", [31, § 102] and "unobvious" [31, § 103].

For most types of inventions, the first two requirements usually present little difficulty. Generally speaking, an invention is *useful* if the invention has an utilitarian or commercial value; an invention is *new* if it is the first embodiment of the idea in a useful thing or process; and an invention is *unobvious* if it would not have been obvious to a person reasonably skilled in the pertinent art, given what already existed in the particular field. This last requirement often is the most difficult barrier for patenting a new invention since often it is very subjective to determine whether the differences between the new invention and the prior state of the art are *obvious* solutions to known problems. The four mentioned categories (process, machine, manufacture, or composition of matter) have - together with the requirements of utility and novelty - the function to restrict the set of patentable inventions; explicit prohibitions do not exist. The process for obtaining a patent on an invention typically starts with a patent attorney preparing and filing a patent application for the inventor and owner of the invention with the United States Patent and Trademark Office (USPTO). The first inventor is entitled to the patent over any subsequent inventors - even if the subsequent inventor applies first – as long as the first inventor can prove the earlier date of the invention.

Table 2: Patents granted by class in the years 1997-2001 [32]

Class	1997	1998	1999	2000	2001	Amount
700	349	660	536	465	660	2670
701	329	510	684	824	1253	3600
702	350	517	512	517	574	2470
703	224	297	301	285	275	1382
704	365	611	627	534	610	2747
706	202	305	128	130	157	922
707	580	1189	1283	1131	1256	5439
716	191	269	246	236	404	1346
717	128	306	406	370	467	1677
Amount	2369	4004	4187	4027	4996	Total: 22253

The application must be filed not later than one year after: public use of the invention, the placing on the market of the invention for sale in the U.S., or the publication of a description of the invention anywhere in the world. Table 2 clarifies granted patents in the field of „Data Processing“[1] in the U.S. between 1997-2001 [32]. A detailed overview of positive and negative patenting decisions involving software is given in [27].

2.2.2 Economic Perspective

Patents and the incentive problem: The standard economic rationale for patents is to protect potential innovators from others´ imitation, thereby providing incentives to incur the cost of innovation. The innovator receives a temporary monopolistic position [3]. The usage of the patent system therefore has two essential advantages:

- The patent owner (monopolist) is able to claim higher prices and larger market shares.
- The time frame for skimming the market will be artificially extended.

The patent owner has the possibility to offer licenses and the chance to participate in the development or improvement of future innovations by licensees [28]. Since the patenting process is expensive (one application in Europe can cost up to € 50.000 [1]), small and medium-size enterprises (SMEs) in particular are discriminated. As a consequence, scarce financial resources constitute substantial barriers to patenting among SMEs. Hence, nondisclosure can be an optimal strategy [15].

Jaffe suggests that patents inhibit other innovation activities, for example by preventing access to licenses needed for improvements. This is characterized as *negative after deductions effect* [22]. Furthermore *Kortum* & *Lerner* point out that despite decreasing R&D expenditure, the number of patents in the U.S. is increasing quickly. They substantiate these correlations with company-wide advanced innovation management [24]. The same perception is represented by *Bessen* & *Maskin*. Moreover they discuss about *trivial patents* which conduct knowledge that is considered common knowledge and therefore not patentable [4].

Patent race and cross licensing: Because each innovation can only be assigned once, innovators often find themselves in a patent race. Although the *losers* face R&D and patent application costs, they attain no revenue. In this context *Dasgupta* & *Stieglitz* speak of a socially unwanted situation [10]. At the same time, the licensing process offers a possibility for reducing future innovation costs of other innovators [26] [28]. The winner normally is not engaged in offering licenses. Licensing implies competition and endangers the patent owner's monopoly position. This leads to the inhibition of R&D by other inventors with concepts for improvements on a patented product [4].

If, for example, another actor has invested in developing an improvement to a product, the firm holding the original patent may use its monopoly position to appropriate some of the value created by the complementary innovation. This can occur even if a second firm ob-

[1] Class 700: Generic Control Systems or Specific Applications, Class 701: Vehicles, Navigation, and Relative Location, Class 702: Measuring, Calibrating, or Testing, Class 703: Structural Design, Modeling, Simulation, and Emulation, Class 704: Speech Signal Processing, Linguistics, Language Translation, and Audio Compression/Decompression, Class 706: Artificial Intelligence, Class 707: Database and File Management, Data Structures, Or Document Processing, Class 716: Design and Analysis of Circuit or Semiconductor Mask, Class 717: Software Development, Installation, and Management.

tains a patent on the improvement. If the second firm can market its innovation with the consent of the first firm, the first firm can increase its profits on the second´s account by bargaining to license the complementary technology at less than full value. This *holdup problem* reduces R&D in complementary technologies through inventors reducing the expected return on their investment [9]. Although it appears as though licenses will never be assigned in such situations, it still happens. Nowadays patents offer the function of *currencies*. If a company needs another firm´s license for its own activities, it tries to exchange its own license with that of the other license holder. This operation is referred to as *cross licensing*. Patents are used as *weapon in competition* and play a decisive role second to negotiations [20].

Table 3: Positive and negative aspects of patents

Positive aspects	**Negative aspects**
Microeconomic perspective	
Imitators are discouraged through the consequences of infringement. Patents also hamper piracy. An extended time frame for skimming the market is given.	Substantial costs: Costs of patent description and of patent agents, patent application and the costs of assignation of patents, costs of the extension of a patent.
Patents enforce the first mover advantage and therefore the de-facto-standardization (positive feedback loops).	Patent infringement is difficult to control, especially in embedded systems. Moreover discovery of infringement is very expensive.
Patents represent assets strengthening the relative competitive position.	The liability of disclosure (6 months) opens the ideas for others and gives them the chance to market the ideas earlier.
The liability of disclosure (6 months) opens the ideas of others for own developments.	Development costs increase, because of licenses or bypass of patented developments. Improvements are only possible on a complementary way (low rate of code re-using). Risk of market exclusion.
Expending of development costs through the chance of being monopolist and claiming higher prices.	Patents can hamper interoperability.
Licensing and cross licensing are possible.	
Macroeconomic perspective	
Patents are an important incentive for spending capital in R&D.	Decrease of development efforts (holdup problem), cannibalizing the own network.
	Decrease of product variety.
	Inhibition of technical progress through the denial of licenses.

Patents, sequentiality, and complementarity: *Sequentiality describes* each successive invention being built on the preceding one. The rate of re-using code is very high [4] [3]. *Complementarity* means that each potential innovator takes a somewhat different research line, thereby enhancing the overall probability that a particular innovation goal will be reached within a given time [4]. The sequential and complementary nature of innovations is widely recognized, especially in high tech industries [17] [18] [9]. Analyses of many innovations found that most of the productivity gains are achieved via improvements to the original innovation (e.g. [13]). Empirical evidence for innovative complementarities is provided by [30] [19].

Table 3 summarizes positive and negative aspects of patenting software. We distinguished between the view of an individual actor (microeconomic perspective) and the macroeconomic perspective.

3. The Model

In the following our model for investigating the economic impact of patents will be introduced. The main difference to existing work in this research field is the approach of a simulation model to augment the small analytical models, proposed by Bessen/Maskin 2000, Green/Scotchmer 1995, Chang 1995 etc. about the impact of additional key factors like different levels of complementarity, cost structures, and multiple periods. The increased complexity, triggered by these parameters circumvents the applicability of analytical methods.

The following assumptions are based on the preceding literature review:

1. The software market is characterized by short innovation cycles. Improvements emerge frequently in a cycle of less than 12 months.
2. The software market is characterized by a high rate of incremental progress. Innovations in this market are profoundly sequential.
3. The market is characterized by a high degree of complementarity.

4. Research and development efforts in one generation become obsolete after a few (3) periods.
5. R&D-efforts have an extensive impact on finding future innovations (3 periods).

Based on these assumptions, we developed a bipartite economic multi-period model comparing a deregulated market without patents to a market using the patent system. The basic model was developed in [21] so only the main elements are presented here. In this paper we focus on simulation results regarding the impact of the length and scope of a patenting system on the firms´ innovation behavior. The model encompasses I actors, representing software manufacturers in a particular segment of the software market (e.g. text processing). The model considers three different company sizes. Based on the topological data of the German software market the actors are organized into sectors of small (80%), medium-size (15%) and large companies (5%) [16]. In each period t one or several parallel innovations lead to the economic profit v_t which is assumed to be constant over time and will be split between the successful actors (analogous to [4]). Therefore, the actors compete with each other for the same innovation in one period. The planning horizon of the model is T.

Another parameter influencing the expected profit are the development costs c_{it}^{d}. The greater the efforts the smaller the profits, but the higher the probability of success. The amount of c_{it}^{d} depends on the company's size. The larger the company the higher the possible development costs. If patenting is possible the companies taking part in the patenting process further have to spend patent process costs c_{it}^{p}.

Based on the assumptions presented above the core of the model is formed by the innovation probability p_{it} which determines the innovation success of actor i finding the innovation in period t. p_{it} is functionally dependent of the following factors:

- A: The development costs, spent in t and in the former 3 periods (assumption 5).
- B: The innovation success in the preceding 3 periods, represented by the binary variables $x_{it-1}, x_{it-2}; x_{it-3}$. x_{it} is equal to one, if actor i found the innovation in period t (assumption 2).
- C: The patenting activities of the other innovators, represented by $\varepsilon_{it} = \{0;1\}$. If patenting without licensing is possible, incremental improvements of others in earlier periods (T_P represents the current time of patent protection, which actual amounts 20 years) have to be found in a complementary way, diminishing the chance of success. This effect decreases the probability, if the innovation in period t was patented by an actor $j \neq i$. The nearer ε_{it} is to 1.0 the lower is the difficulty for finding a complementary way (assumption 3) and therefore the smaller is the scope of patent protection.
- Various weighting (α, β, M) and discount factors (w_d, w_x) (assumption 4) assess the influence of the several parameters, as can be seen in equation 1.

The aggregates A and B are normalized by dividing them to the regarding maximum values. The derivation of equation 1 can be found in [21].

$$p_{it} = \frac{\alpha \frac{A}{\overline{A}} + \beta \frac{B}{\overline{B}}}{M} \cdot C =$$

$$\frac{\alpha \cdot \frac{\sum_{\tau=t-3}^{t} c_{i\tau}^{d} \cdot w_d^{(t-\tau)}}{\sum_{\tau=t-3}^{t} \overline{c}_{i\tau}^{d} \cdot w_d^{(t-\tau)}} + \beta \cdot \frac{\sum_{\tau=t-3}^{t-1} x_{i\tau} \cdot w_x^{(t-\tau)}}{\sum_{\tau=t-3}^{t-1} w_x^{(t-\tau)}}}{M} \cdot \prod_{\tau=t-T_P}^{t-1} \varepsilon_{i\tau}^{(\tau-t+T_P+1)} \qquad (1)$$

$$with \quad \alpha, \beta \geq 0; \quad \alpha + \beta = 1 \quad and \quad M \geq 1$$

The innovation and patenting process consists of four activity steps in each period:

I. Actor i has to decide whether or not to participate in the innovation process, i.e. spending development costs c_{it}^{d}.

II. His research process turns out to be either successful or not, according to his innovation success probability p_{it}.

III. If research is successful, the actor has to decide about taking part in the patent race.

IV. Only one actor can win the patent race. The winner is determined randomly with the same probability for every actor participating in the patent race.

Steps III and IV only occur in the scenario which possesses a legal patent protection system. A risk-neutral actor i will only invest in R&D in period t if his expected net benefit $Exp[v_{it}]$ is positive. The expectation depends on the individual innovation probability, on the elevation of effort, and on the network size. The bigger the network, the more actors will find the innovation resulting in a reduced part of the economic profit.

$$Exp\left[v_{it}^{net}\right] = \frac{v_t}{Exp\left[\sum_{i=1}^{I} x_{it}\right]} \cdot p_{it} - c_{it}^{d} \qquad (2)$$

As an estimator for $Exp\left[\sum_{i=1}^{I} x_{it}\right]$, the number of actors who found the innovation in the period before will be used. The expected value does not include resulting future benefits, because technological progress is difficult to predict and the complexity of the model would increase superproportionally. If the actors can take advantage of an installed patent protection mechanism, the model comprises an additional decision function (3) for evaluating the benefits of patenting, including the probability to win the patenting race. An innovator agrees to the patenting process if the expected actual economic profit minus the patent application costs c^{p} and plus the expected future benefits $Exp\left[BW_t^{PZ}\right]$ of establishing a temporary monopoly is positive. The detailed derivation again can be found in [21].

$$
if\left(\frac{v_t}{\sum_{i=1}^{I} x_{it}} - c^p + Exp\left[BW_t^{PZ}\right]\right) > 0 \tag{3}
$$
$$
\Rightarrow \text{ actor } i \text{ takes part in the patent race}
$$

4. Results

4.1 Parameterization

The following results are based on simulations, which emulate the behavior of 100 software developers in a particular market segment. The actors are grouped into three sectors of company-size (small = 80%, medium = 15%, large = 5%), resulting in different exemplary chosen ranges of development costs. The concrete values are equally distributed within the ranges given in table 4. Every simulation was run about 50 periods (T = 50). The total economic profit per period amounts to v_t = 100 resp. v_t=1500 monetary units.

Table 4: Distribution of development costs

Company sector	Large	Medium	Small
c_{ti}^{d} upper bound	60	40	30
c_{ti}^{d} lower bound	30	20	10

We used the parameterization of the weighting and discount factors in equation 1 as shown in table 5. These values are based on no empirical evidence yet and are only chosen as a starting point for later sensitivity analyses. Using these values the different influence factors are weighted equally within the innovation probability.

Table 5: Constant probability parameters

Further parameters determining the innovation probability		
Weight of prior development costs	w_d	0.9
Weight of prior successful innovations	w_x	0.9
Relative weight of development costs	α	0.5
Relative weight of successful innovations	β	0.5
Market difficulty	M	1.0

4.2 Simulation Results

The following simulation results are shown for two different environments (v_t = 100 or v_t =1500 in every period) to analyze markets with low and high profit potential. Both environments are simulated without (scenario I) and with (scenario II) the availability of a legal patent system. To analyze the impact of different system configurations in all cases the patent length T_p is varied from 1 to 20 periods (20 years is the actual current protection time), and the patent protection scope ε is varied from 1.0 (= no protection) to 0.9 (values lower than 0.9 would result in such a high patent scope, that no innovation activities, except by the first patent owner, were possible).

The first question of our paper focuses on the endemic propensity to monopolize. To examine this question the Herfindahl index is applied. This index is commonly used to measure market concentration in industrial economics. The index is calculated by summing up the squared market shares of each innovator. In order to measure the stability of temporal monopolies we constructed an intertemporal Herfindahl index *HKI* which represents the distribution of the different patents (over time) in the network. *HKI* = 1.0 means every patent within the simulated periods was hold by the same actor, while lower values represent changing patent owners over time.

Figure 2 shows the resulting values for v_t = 100 and v_t = 1500. The higher the patent scope and/or patent length, the higher the tendency of intertemporal monopolization, i.e. at low ε and high T_p rather only one actor will gain all innovations and patents over time. The trend of monopolization is much more distinctive in the low potential market (v_t=100).

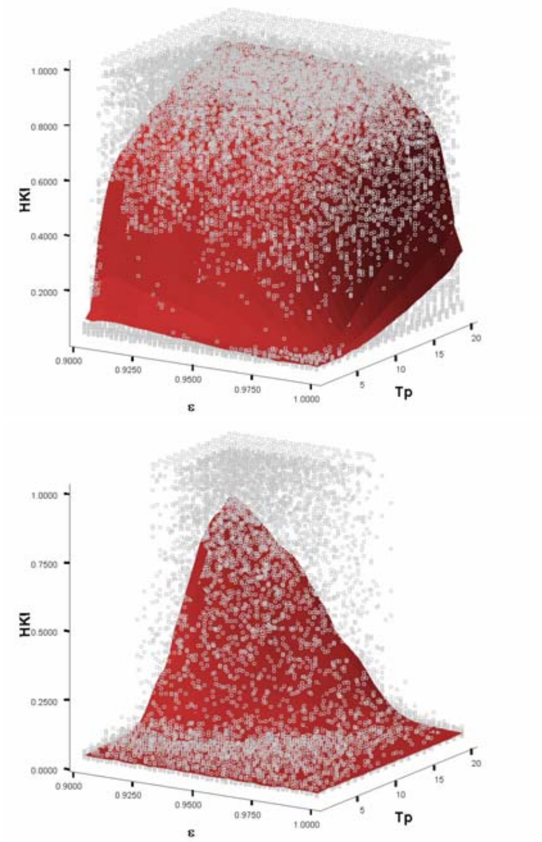

Figure 2: Market concentration index for v_t = 100 (upper diagram) and v_t = 1500 (lower diagram)

The second research question focuses on the relation between patentability and overall innovation rates. In order to answer this question, we measured the number of periods in which at least one actor found the innovation. We again compared the different market potentials (v_t = 100 and 1500) and did four views at two different scopes of patent protection (wide protection (ε = 0.9) and small protection (ε = 0.99)) and two different current times of protection (T_p=5 and T_p=20) while varying the other parameter (abscissa). Figure 3 and 4 show the results of the different constellations for a small market value (v_t=100).

The upper diagram in figure 3 shows that by varying patent duration (T_p=1 up to T_p=20) with a constant small protection width (ε = 0.99) the scenario with patent protection performs better with a patent current time between 6-15 periods. Below 5 periods both scenarios have on average 25 periods with innovations found. (Caused to the low possible profit the decision function (eq. 2) leads to oscillations in decision and innovation behavior.)

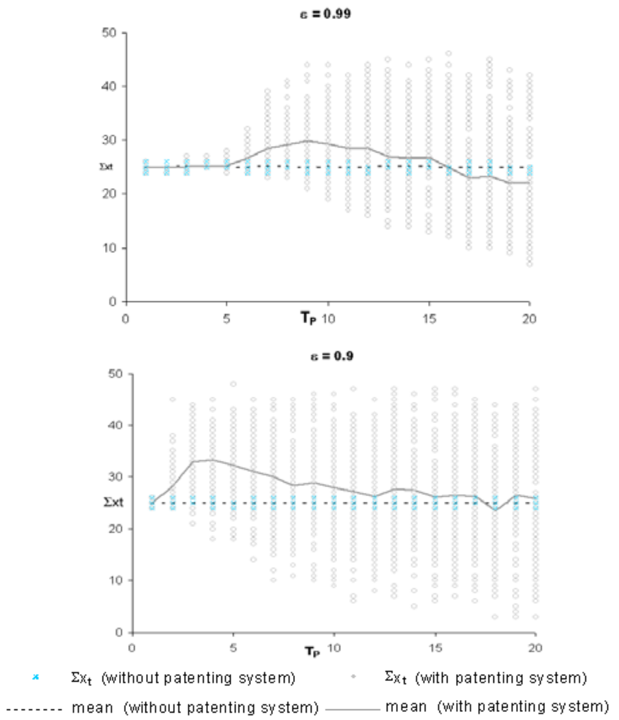

Figure 3: Number of innovations found with v_t = 100 (varying patent length T_p at two different levels of ε)

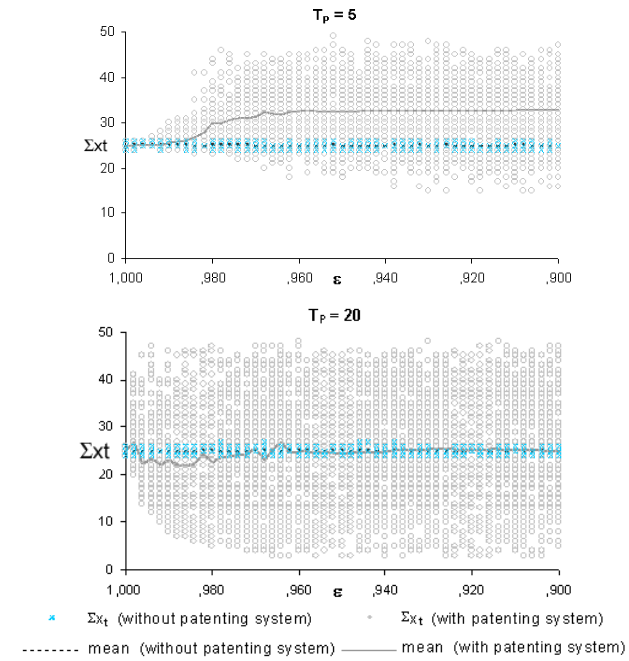

Figure 4: Number of innovations found with v_t = 100 (varying patent scope ε at different levels of T_p)

Figure 5 and 6 represent the corresponding results for the same parameter constellations in a high value market (v_t=1500).

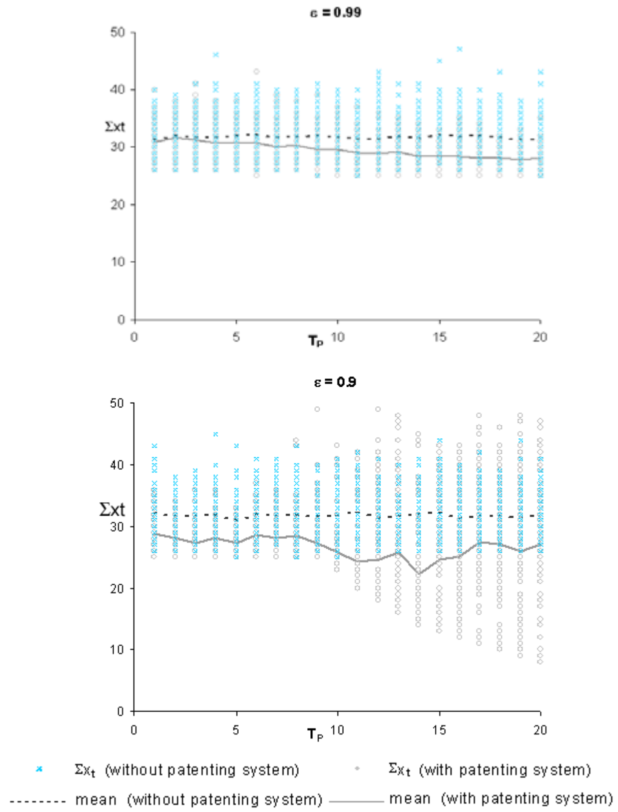

Figure 5: Number of innovations found with v_t = 1500 (varying patent length T_p at two different levels of ε)

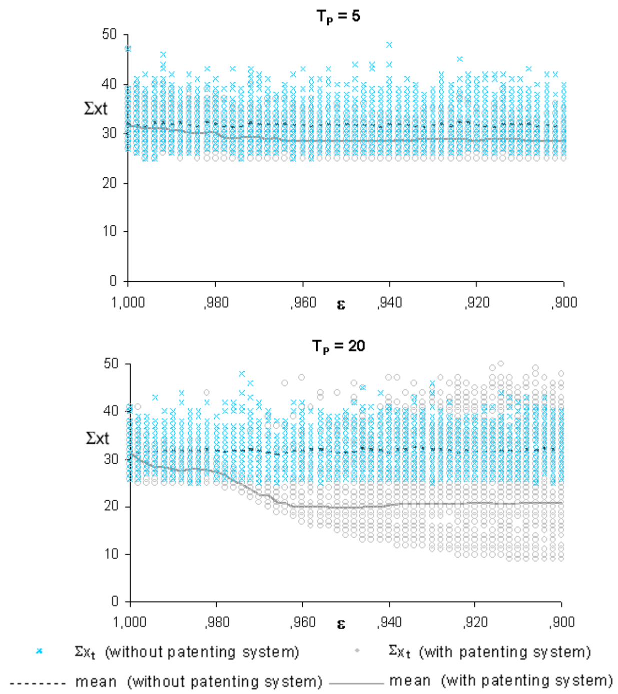

Figure 6: Number of innovations found with v_t = 100 (varying patent scope ε at two different levels of T_p)

In this situation the results have changed. The overall level of "innovative periods" is higher because the larger market potential provokes more actors to invest in R&D. The scenario without patent protection dominates in all cases. The innovations found on average always are higher. The longer the run time the bigger the difference in favor of the scenario without patents. With constant patent lengths (T_p=5 and T_p=20) the same results occur. It is noteworthy that at T_p=20 the patent protection system performs very badly between the patent scopes of ε=0.98 and ε =0.9. In this area only 20 innovations on average could be found. In markets with a high innovations value, the no-patent scenario dominates the patent scenario in every case. This is more with long patent current times and less with short run times. Comparing these results it can be summarized that within a low market potential combinations of rather high patent scope and rather short patent duration (3-5 periods) a legal patent system provides worse results (see figures 3&4) while it always results in positive effects in high value markets (figure 5&6).

In a next step, we analyzed the innovation success of the different market sectors in more detail, i.e. the relative innovation success between small, medium-size and large companies. For that purpose, the total number of innovations (including simultaneously found innovations) was counted and divided by the market share of the regarding company sector (i.e. small, medium or large companies). This success index was normalized to a value between 0 and 1.

$$\text{successindex}(\text{sector}) = \frac{\sum_{t=1}^{T} \sum_{i \in NW_{sector}} x_{it} \Big/ \text{share}(\text{sector})}{\sum_{\text{sector} \in \{\text{small},\text{medium},\text{large}\}} \left(\sum_{t=1}^{T} \sum_{i \in NW_{sector}} x_{it} \Big/ \text{share}(\text{sector}) \right)} \quad (4)$$

$$\forall\, sector \in \{small, medium, \text{large}\}$$

As can be seen in figure 7, only in the v_t=100 environment the relative success of the respective sector changes with the patent length and scope. Without patent protection (the outer left dataset in each chart) in most cases the small companies are the most successful actors followed by the medium companies. In the case of a rather low patent scope (ε=0.99) and patent length of 6 to 10 periods the large companies reached relatively more innovations. At low ε the relations evolve inversely. Of course these results depend on the chosen cost structures, but it could be shown that in particular constellations and especially with constant cost structures the variation of patent system properties influences the success in a different way. This phenomenon has to be taken into account when designing welfare efficient patenting systems.

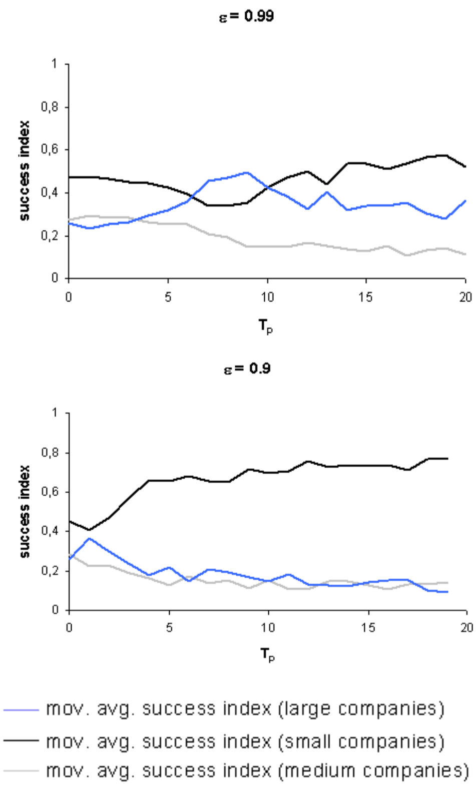

Figure 7: Innovation success by company's size for v_t=100 (different levels of ε)

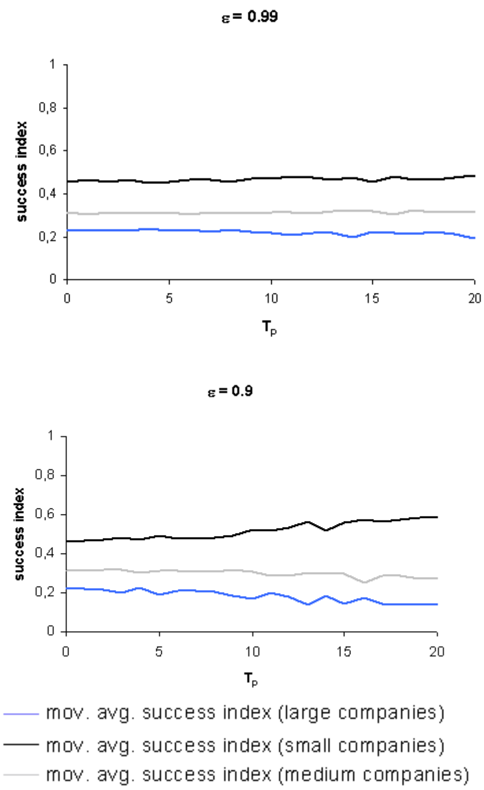

Figure 8: Innovation success by company's size for v_t=1500 (different levels of ε)

5. Conclusion and Further Research

The goal of this paper was an analysis of the impact of software patents on the innovation activities of the software market. In this context, software development was characterized by its *sequentiality*, *complementarity*, utilization and availability of *open code as well as* the necessity to ensure *interoperability*. We developed a bipartite model for comparing environments with and without a legal patent system. Based on the characteristics (e.g. sequentiality and complementarity) we identified the development costs and the existence of previous innovations as the two key factors for innovation success. In the patent scenario the patent itself will have an additional effect. Computer-based simulations revealed that patent protection within low-potential markets outperforms the scenario without patenting system while the opposite holds for high-value markets. For both systems there is a propensity to monopolize, which is more distinctive in the low value market. The quantitative results of course are only interpretable within the chosen environment (parameterization, modeling of decision functions etc.). Nevertheless from the model the following general findings can be derived:

Patents lead to more or less intertemporal monopolies. Both the patent width and the patent length as key determinants of a legal patent system from a macroeconomic view can not be determined independent of the particular market properties (innovation difficulty, cost and market structure, market potential).

In some parameter constellations (lower market potential) a patent system leads to structurally different outcomes for the different market sectors.

As a next step, we will validate the findings using empirical data (esp. development costs and incentives for software producers) from conducted cases of software companies. Based on this research a sensitivity analysis of all parameters is necessary to determine the validity area of the made conclusions. Further the model will be extended about the possibility for cross-licensing and the actors' development costs will be endogenized to gain more favourable results about the individual incentive structure. Based on these steps of validation and extension the model could support in determining the necessity of a patent system or evaluating the optimal length of patent protection subject to the particularities of the software market.

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