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The Impact of Software Patents on the Structure of the Software Market: A Simulation Model

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Abstract

The issue of software patents is widely discussed in Europe today. The standard economic rationale for patents is to protect potential innovators from imitation, which ultimately provides the incentive to incur the costs of innovation. This incentive topic is strongly discussed in network effect markets such as the software market. We identified five characteristics of software which are crucial for the question of patenting and its consequences: Sequentiality, complementarity, the utilization and availability of open code and the necessity to ensure interoperability as well as the digital character of the goods. Based on seven assumptions affiliated from the literature, we developed a bipartite central probability model comparing a deregulated market without patents to a market using the patent system. The main objectives were to evaluate the frequency of innovations in the software market and on the other hand to investigate monopolistic tendencies. We simulated our model under two different parameter constellations (optimistic and pessimistic environment from a patent owner's view). Selected snapshots of exemplary simulations showed that strong patent protection circumvented technical progress from a macroeconomic perspective. Moreover, in the long run only one actor (monopolist) dominated the market. Reducing the protection strength (pessimistic environment) resulted in partially contrary effects.

Keywords

Property rights, patents, incentive, software, patent race, cross licensing

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1. Introduction

Software patents are a topic currently being discussed in Europe and Germany. According to article 52 of the European Patent Agreement of 1973, computer programs are not inventions and therefore not subject to European patent law. But in a strict sense this is only valid for "*software as such*". Accordingly, European adjudication grants patents for software. This is more comparable to the practice found in the United States, where not only software but also business methods are patentable. Wolfgang Tauchert from the German Patent- and Trademark-office estimated the number of granted patents involving software in 2001 to be over 500. In this context the term "*computer implemented inventions*" is used (DPMA 2002).

In the attempt to narrow this discrepancy between law and adjudication, the European commission conducted a pan-European questioning of the software industry. As a consequence the European commission proposes to overtake the US approach, except the patenting of business methods. Addressing this problem, we developed a two-stage model comparing economic efficiency of systems with and without patents. The purpose of this paper is to answer the following two questions:

1) ***In which scenario (patents vs. no patents) can we expect a higher level of innovation in any given time scope? In other words: which scenario exhibits stronger incentives to innovate?***
2) ***How do the scenarios differ in terms of the endemic propensity to monopolize?***

After an overview of software patents in the economic literature (section 2) the software market is analyzed (section 3). Based on this, in section 4 an economic simulation model incorporating local incentives associated with patents and their implications on system behavior is developed. Section 5 shows first simulation results.

2. Literature Review

Various approaches in the economic literature analyze the correlation between patents, innovation, and social welfare. Software patents in particular are often discussed in a controversial context. We differentiate in four viewpoints:

- Software patents and the incentive problem
- Patent race and cross licensing
- Network effects and standards
- Special features of software

Software Patents and the Incentive Problem

The standard economic rationale for patents is to protect potential innovators from imitation, thereby providing the incentive to incur the cost of innovation. The innovator receives a temporary monopolistic position (Besen & Raskind 1991). The usage of the patent system in this point 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 extended artificially.

In the future, the patent owner has the possibility of offering licenses and the chance to participate in the development or improvement of future innovations created by other innovators (Ordover 1991). Because the patenting process is expensive (one application in Europe can cost up to € 30.000 (Beckmann 2002), small and medium-size enterprises (SMEs) in particular are disadvantaged. As a consequence, scarce financial and know-how resources establish substantial barriers to patenting among SMEs. An optimal company strategy could be nondisclosure (Friedewald, Blind and Edler, 2002).

Nordhaus et al. focus on the problem resulting when technological improvements are used by a very small group of users. From an economic perspective due to their high costs, patents are a suboptimal solution compared to the scenario without patents (Nordhaus 1969; Gilbert & Shapiro 1990; Klemperer 1990).

Jaffe suggests that patents inhibit other innovation activities, e.g. in such a matter, that the access to licenses needed for improvements will be denied. This is characterized as *negative after deductions-effect* (Jaffe 1999). *Kortum* and *Lerner* furthermore point out that despite decreasing R&D expenditure, the number of patents in the US is increasing quickly. They substantiate these correlations with company-wide advanced innovation management (Kortum & Lerner 1997). The same perception is represented by *Bessen* and *Maskin*. Moreover they discuss about *trivial patents* which conduct knowledge that is counted among the state of the art, and therefore not patentable (Bessen & Maskin 2000).

2.1 Patent Race and Cross Licensing

As shown previously, the process of patent application is very cost intensive. Because each patent can only be assigned once, innovators often find themselves in a patent race. Only one can be the winner of this race. Although the *losers* of the race have the same R&D and patent application costs, they attain no revenue. In this context *Dasgupta* and *Stieglitz* speak of a socially unwanted situation and missing commensurability (Dasgupta & Stieglitz 1980). On the other hand the licensing process offers a possibility for reducing the future innovation costs of other innovators (Loury 1979; Ordover 1991). 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 (Bessen & Maskin 2000).

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 obtains 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 at the expense of the second 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 (Chang 1995).

Although it appears as though licenses will never be assigned in such situations, it still happens. Nowadays patents possess the function of *currencies*. If a company needs another firms 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 (Harhoff & Reitzig 2000).

2.2 Network Effects and Standards

The software market is determined by positive network effects deriving from the need of product compatibility (Ceci & Kain 1982). The willingness to adopt a product innovation correlates positively with the number of existing adopters (Weitzel, Wendt and von Westarp 1999).

Markets with network effects finally will lock-in to a monopoly situation with one standard winning total market share. In some respects standards make further innovations and diversity difficult (Farrell & Saloner 1986). On the other hand, standards provide for compatibility and are a prerequisite for cooperation benefits. An essential assumption for collaboration benefits are open interfaces so that interoperability between different systems and applications can be realized. Many SMEs would have no access to large customer networks without this interoperability. They normally are not able to establish company-standard-based networks (Blind, Edler, Nack and Straus 2001). The absence of open interfaces may lead to a lock-in of existing customers, and therefore to monopoly network structures, because the changing costs are to high for the current participants (Farrell 1989). Patented interfaces boost this problem.

Stolpe claims the necessity of installing strong property rights, particulary in markets with network effects, because they enable innovators to internalize positive externalities, and to achieve a high market penetration without product piracy and imitation (Stolpe 2000).

2.3 Special Features of Software

Software development is basically distinguished from other products by five characteristics which are decisive for the question of patenting and its consequences:

a) *Sequentiality and Complementarity*

Sequential means that each successive invention is built on the preceding one. The rate of re-using code is very high (Bessen & Maskin 2000; Besen & Raskind 1991). *Complementary* means that each potential innovator takes a somehow different research line, thereby enhancing the overall probability that a particular innovation goal will be reached within a given time scope (Bessen & Maskin 2000). The sequential and complementary nature of innovations is widely recognized, especially in high tech industries (Gort & Klepper 1992; Green & Scotchmer 1995; Chang 1995). Analyses of many innovations found that most of the productivity gains are achieved via improvements to the original innovation (e.g. (Enos 1962)). A variety of empirical studies found strong evidence of innovative complementarities (Spence 1984; Jaffe 1986; Grilichs 1992). Figure 1 shows the re-use of code in the German software industry, split in primary (IT-Service providers and manufacturers of data processing equipment) and secondary industry (manufacturing systems engineering, electrical engineering, vehicle construction, telecommunication and financial services):

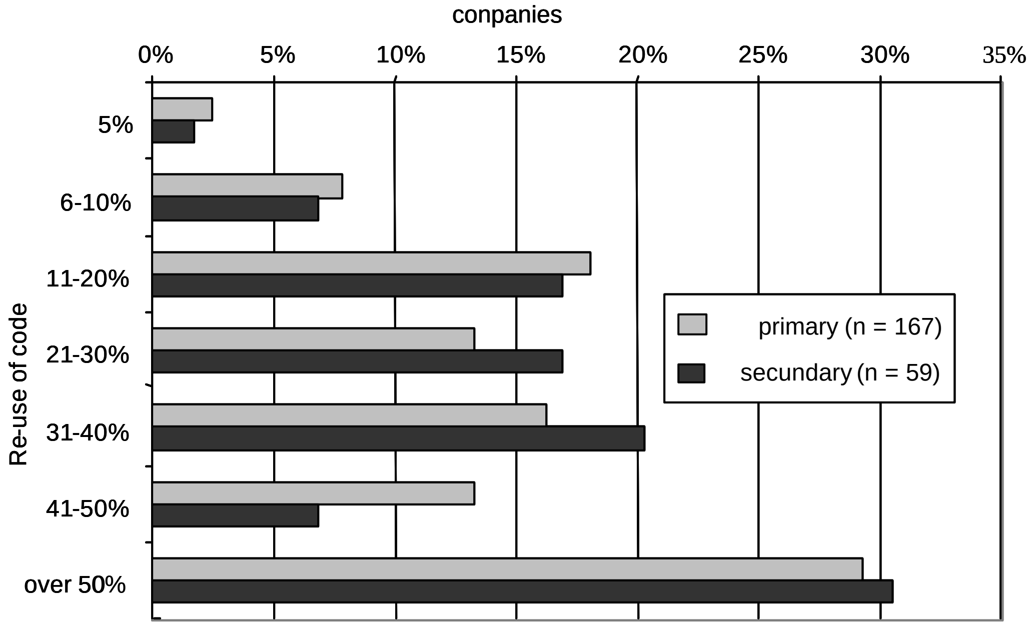

Figure 1: Re-use of code (Blind et al. 2001)

b) Utilization and Availability of Open Code

Open code is one of the most important external factors for software development. The strongest usage emanates from independent developers, but recently the re-use of open source software by medium-size and large companies has increased as well (Friedewald et al. 2002). Open Source has 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.

c) Interoperability

Attributes of software that bear on the ability to interact with specified systems and with other software products are defined as interoperability (ISO 1991). The *European computer law directive* describes interoperability as the capability of a computer program to exchange information (Fromm & Nordemann 1998). Interoperability with customer and supplier software and with competitive and complementary products can be achieved by disclosure of interfaces; the disclosure of code plays a subordinate role here. For example, patents on protocols required for interoperability are a barrier when trying to implement compatible solutions.

d) Digital Goods Character

Emery has studied the character of software, such as fast diffusion and diversification. He found evidence that, due to the high diffusion of information technologies, software developers (innovators) compared to imitators are at a disadvantage, because copying and imitating becomes easier. For this reason he favors software patents (Emery 1996).

2.4 Summary of Positive and Negative Aspects

The following table summarizes positive and negative aspects of patenting software. We distinguished between the view of an individual actor (microeconomic perspective) and a macroeconomic perspective.

Positive aspects	Negative aspects
Microeconomic perspective	
Discourage of imitators 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 the monopolist and claiming higher prices.	Patents can hamper interoperability.
Licensing and cross licensing are possible.	
Macroeconomic perspective	
Patents are an important incentive for spending money in R&D.	Decrease of development efforts (holdup problem), cannibalize the own network.
	Decrease of variety of products.
	Inhibition of R&D by others through the denial of licenses.

Table 1: Positive and negative aspects of patents

3. Topological structure of the German software market

In 2001 the revenue of the German market for software and IT services (primary and secondary industry) increased by about 12% to € 34 billion (EITO 2001). Altogether both industries consist of 19.300 companies producing software (10.568 in primary branch and 8,990 in secondary branch) (GfKM 2000).

Employees	Companies producing software (primary industry)	Companies producing software (secondary industry)
With 1-9 employees	8.173	4.058
With 10-49 employees	1.735	2.242
With 50-199 employees	475	1.326
With >199 employees	185	1.364
Total	**10.568**	**8.990**

Table 2: Structure of the German software market

The German **I**nformation and **C**ommunication **T**echnology market (ICT market) has been impacted heavily by the economic slowdown, even if the various markets have been affected in a different level, stronger in the hardware segments, and fewer in software and services (Bitkom 2002). The subsequent data refers to the primary and secondary branch.

German software market value, billion €					
	1999	2000	2001	2002	2003
Software products	12.6	14.4	15.2	15.1	15.1
Expansion rate		14.2%	5.4%	-0.80%	-0.30%

Table 3: German software market

The total effort for Research and Development averages € 1.359 million in the primary branch (GfKM 2000). Therefore on average a company in the primary branch expends € 129.000 for R&D.[1]

4. Software Market and Patents - Simulation Model

4.1 Assumptions

The following assumptions are based on the preceding literature review and the analysis of the software market:

1. The software market is characterized by short innovation cycles. Improvements emerge frequently in a cycle of less than 12 months.

[1] $\frac{1.359 \quad million \quad €}{10.568 \quad companies} = 129.000 \quad €$

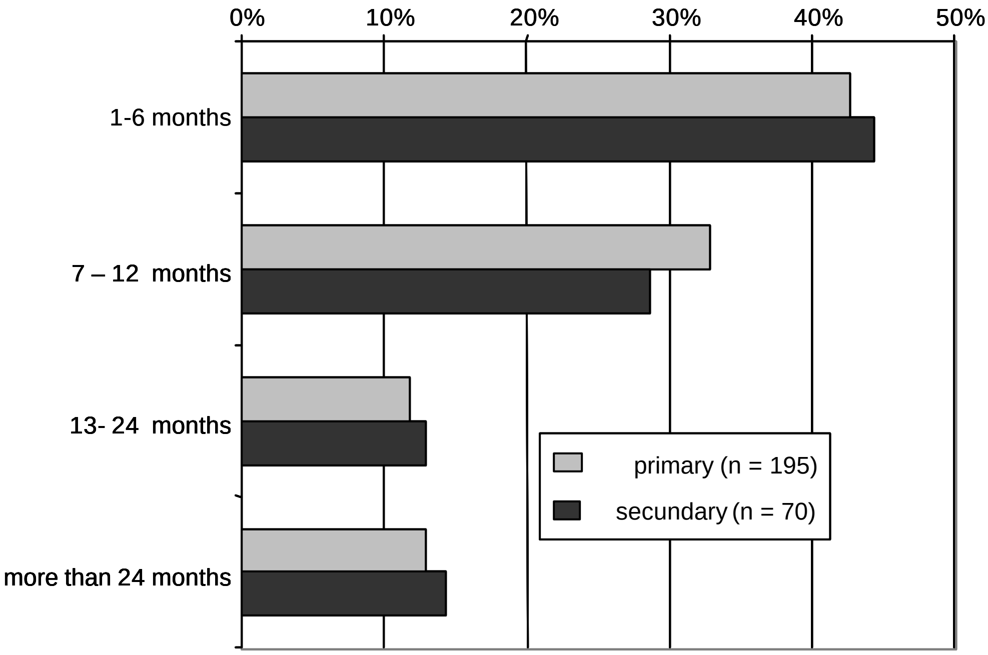

Figure 2: Innovation cycles (Blind et al. 2001)

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 periods.
5. The structure of the German software market is characterized by a large number of SMEs.
6. The software market is characterized by strong network effects.
7. R&D-efforts have an extensive impact on finding future innovations.

4.2 Model Structure

Based on these assumptions, we created a bipartite economic probability model comparing a deregulated market without patents to a market using the patent system.

Structural Parameters

The model encompasses *I* actors**,** representing software manufacturers in a special segment of the software market (e.g. text processing). Therefore they compete against each other for the same innovation in a period. The model considers three different company sizes. Based on the topological data of the German software market the actors are determined as small (80%), medium-size (15%) and large companies (5%).

The planning horizon of the model is *T*. Based on assumption 1 and 2, we assume, that all actors have to decide for investment in development in every period anew and then are able to find the innovation.

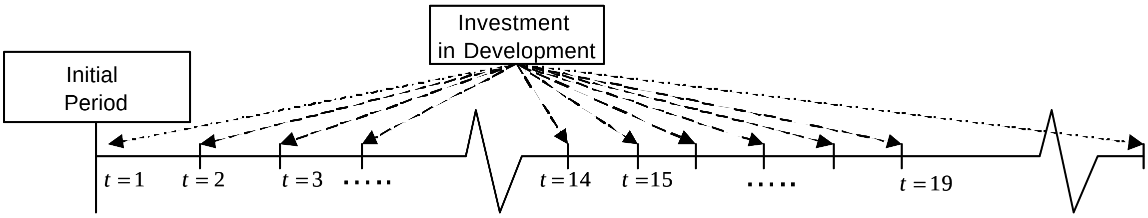

Figure 3: Development timeline

Monetary Parameters

In each generation one or several parallel innovations lead to the economic profit v_t which is assumed to be constant over time and will be split to the successful actors (analogous to the model of Bessen & Maskin (2000)).

$$n_t = \sum_{i=1}^{I} v_{it} = \bar{n} \qquad \forall t = 1..T$$

Equation 1: Economic profit

Another parameter influencing the expected profit are the development costs c_{it}^{d} in every period. The greater the efforts the smaller the profits, but, the higher the probability of success, as will be shown later. The amount of c_{it}^{d} depends on the company's size.

If patenting is possible the companies taking part in the patenting process have to spend patent process costs c_{it}^{p} which include:

- costs of patent description and of patent agents,
- patent application and the costs of assignation of patents,
- costs of the extension of a patent.

The second and third item which only have to be paid by the winner, are of marginal weight.

Probability Parameters

The determination of the actor's probability p_{it} for finding the innovation in period t forms the core of the presented model. p_{it} is functionally dependent of the following parameters:

- Development costs, spent in t and in the former 3 periods: $c_{it}^{d}, c_{it-1}^{d}, c_{it-2}^{d}, c_{it-3}^{d}$.
- 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.
- Existence of patents: if patenting without licensing is possible, incremental improvements of others in future periods have to be found in a complementary way, what diminishes their chances for success (assumption 3). This effect is represented by e_{it} which decreases the probability, if the innovation in period t was patented by an actor $j \neq i$.

$$\boldsymbol{e}_{it} = \begin{cases} e < 1 & if \quad z_{it} = 0 \quad \wedge \sum_{j=1}^{I} z_{jt} = 1 \\ 1 & else \end{cases}$$

Equation 2: Influence of existing patents

The binary variable z_{it} reflects the successful patenting process for actor *i's* innovation in period *t*. Existence of patent protection in Europe persists for 20 years and therefore influences the others innovation probability for 20 periods.

The degree of impact of the included historical parameters decreases with a growing time gap. This effect will be realized by using reverse discounting factors w_d and w_x ($0 < w_d < w_x < 1$) for diminishing the respective historical parameters $c_{it}^d, c_{it-1}^d, c_{it-2}^d, c_{it-3}^d$, and $x_{it-1}, x_{it-2}, x_{it-3}$. Stronger impact of later patents will be realized by exponentiating ε.

$$\text{A:} \sum_{t=t-3}^{t} c_{it}^d \cdot w_d^{(t-t)} \qquad \text{B:} \sum_{t=t-3}^{t-1} x_{it} \cdot w_x^{(t-t)} \qquad \text{C:} \prod_{t=t-20}^{t-1} \boldsymbol{e}_{it}^{(t-t+21)}$$

Equation 3: Factors of innovation probabilities

Terms A and B have to be normalized to values below one. Therefore the respective maximal parameter values have to be determined by inserting the upper limits of the included parameters. $\bar{c}_t^d$ is the upper bound of large companies' development costs:

$$\overline{A}: \sum_{t=t-3}^{t} \bar{c}_{it}^d \cdot w_d^{(t-t)} \qquad \overline{B}: \sum_{t=t-3}^{t-1} w_x^{(t-t)}$$

Equation 4: Normalization of innovation probability factors

Within the probability function the normalized components are weighted again, to adjust the relative strength of the factors´ impact. At least, the whole construct is divided by M, which represents the overall difficulty to find innovations in the particular market.

$$p_{it} = \frac{a \frac{A}{\overline{A}} + b \frac{B}{\overline{B}}}{M} \cdot C = \frac{a \cdot \frac{\sum_{t=t-3}^{t} c_{it}^d \cdot w_d^{(t-t)}}{\sum_{t=t-3}^{t} \bar{c}_{it}^d \cdot w_d^{(t-t)}} + b \cdot \frac{\sum_{t=t-3}^{t-1} x_{it} \cdot w_x^{(t-t)}}{\sum_{t=t-3}^{t-1} w_x^{(t-t)}}}{M} \cdot \prod_{t=t-20}^{t-1} e_{it}^{(t-t+21)}$$

$$with \quad a, b \geq 0; \quad a + b = 1 \quad and \quad M \geq 1$$

Equation 5: Innovation probability

Because the necessary values do not exist in the early periods the following conventions are made:

$$c_{it}^d = 0, \qquad x_{it} = 0, \qquad \boldsymbol{e}_{it} = 1 \qquad \forall t < 1$$

Equation 6: Conventions for parameter values in t<1

Decision Process

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. The research process turns out to be either successful (x_{it}=1) or unsuccessful (x_{it}=0), according to the innovation success probability p_{it}.

III. *If* x_{it}=1, the actor has to decide about taking part in the patent race $\xrightarrow{then}$ (y_{it}=1).

IV. Only one actor can win the patent race. The winner is determined by a random generator with equal probability for every actor, taking part in the patent race. If *i* is the winner, then z_{it}=1, otherwise z_{it}=0.

(Steps III and IV only occur, if the model is equipped with a legal patent protection system.)

A risk-neutral actor *I* in period *t* will only invest in R&D if its expected net benefit E(ν_{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. u_{it} represents the resulting decision.

$$E\left[n_{it}^{net}\right] = \frac{n_t}{E\left[\sum_{i=1}^{I} x_{it}\right]} \cdot p_{it} - c_{it}^{d};\quad u_{it} = \begin{cases} 1 & if \quad E\left[n_{it}^{net}\right] > 0 \\ 0 & else \end{cases}$$

Equation 7: Decision function for investing in R&D (step I)

As an estimator for $E\left[\sum_{i=1}^{I} x_{it}\right]$ the number of actors who found the innovation in the period before will be used:

$$E\left[\sum_{i=1}^{I} x_{it}\right] = \sum_{i=1}^{I} x_{it-1} \qquad \left(E\left[\sum_{i=1}^{I} x_{it}\right] = 1 \text{ if } \sum_{i=1}^{I} x_{it-1} = 0 \right)$$

Equation 8: Decision function for investing in R&D (appendix)

The expected value does not include resulting future benefits, because the complexity of the model increases in oversized wise, furthermore the technological progress is not predictable in the software market.

If the actors can take advantage of an installed patent protection mechanism, the model implements an additional decision function for evaluating the benefits of patenting, including the probability to win the patenting race. Therefore a binary variable y_{it} is equal to one if actor *i* wishes to patent his innovation. Every innovator agrees to the patenting process if the economic profit exceeds the sum of all innovations multiplied with c^p.

The future utility of patenting in present was not taken into account. This extension will be made in future work.

$$y_{it} = \begin{cases} 1 \quad if \quad \dfrac{v_t}{\sum_{i=1}^{I} x_{it}} - c^p > 0 \\ 0 \quad else \end{cases}$$

Equation 9: Decision for patenting (step II)

The decision process can be described as a game theoretical problem with I players. With two players the following situation is given:

		$Agent = 1$	
		$S_{21}=(y_2=1)$	$S_{22}=(y_2=1)$
$Agent = 2$	$S_{11}=(y_2=1)$	$\frac{v_t}{2} - c^p; \frac{v_t}{2} - c^p$	$v_t - c^p; \; 0$
	$S_{12}=(y_2=0)$	$0; \; v_t - c^p$	$\frac{v_t}{2}; \frac{v_t}{2}$

Table 4: Two person game

If $v_t > c^p \sum_i^I x_{it}$, s_{11}/s_{21} becomes the only *Nash*-equilibrium and the Pareto-optimum will not occur. Therefore the actors are in a prisoner's dilemma.

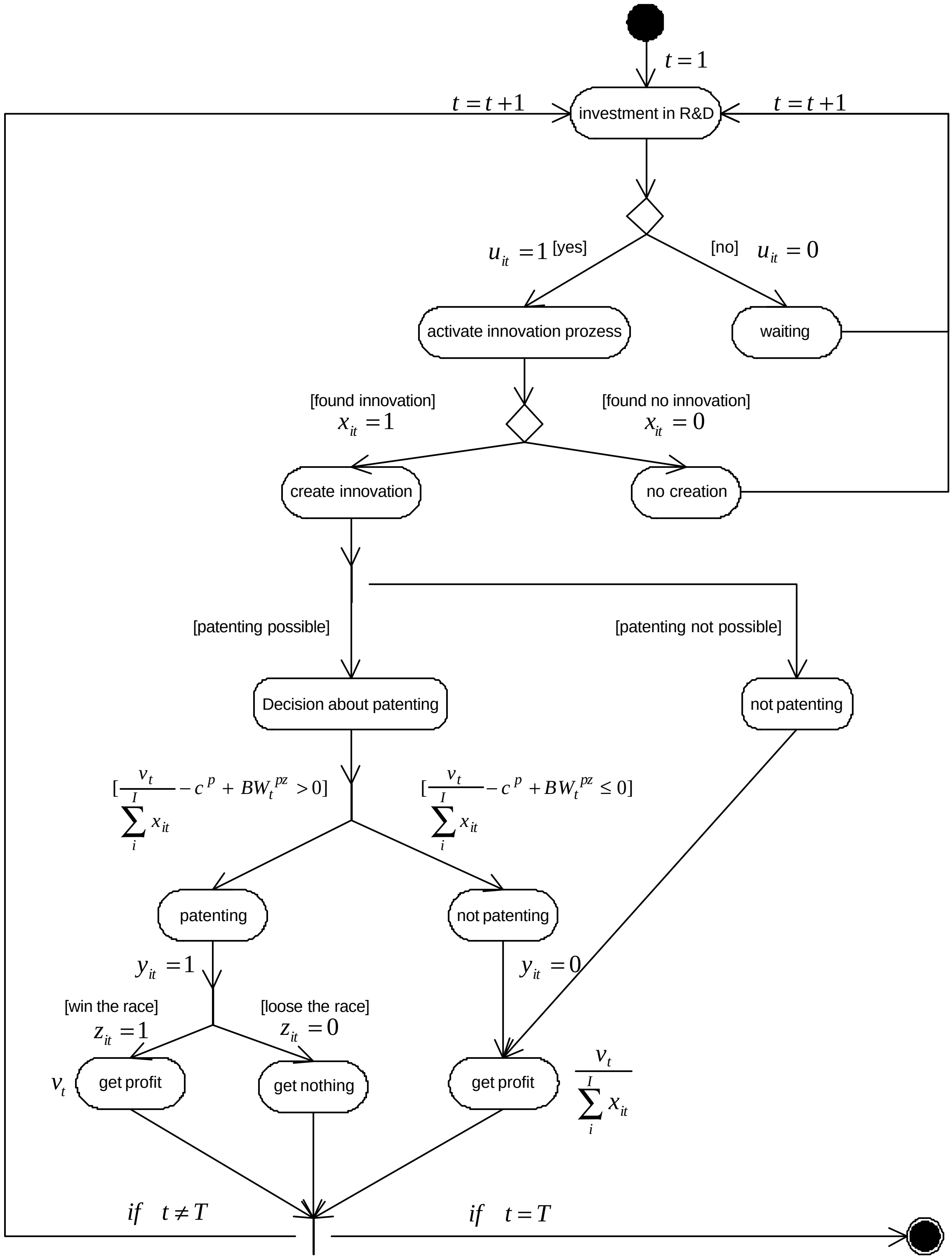

Figure 4: Activity diagram

From a macroeconomic view, the main aim is to find as much as possible generations with innovations.

$$\max \sum_{t=1}^{T} x_t \quad with \quad x_t = \max \quad (x_{1t},....x_{It})$$

Equation 10: Macroeconomic objective

The two key questions are:

1) ***In which scenario (patents vs. no patents) can we expect a higher level of innovation in any given time scope? In other words: Which of these scenarios exhibits stronger incentives to innovate?***

The first part of question, the number of innovations over the time, will be addressed by equation 10. For ascertaining the second part the average of the expectation values of all participants in one period equation 7 is taken.

2) ***How do the two scenarios differ in terms of the endemic propensity to monopolize?***

The number of innovations will be condensed into the Herfindahl-index used in industrial economics to measure market concentration. The index is calculated by summing up the squared market shares of each innovator.[2]

$$HF_t = \sum_{i=1}^{I} \left(\frac{v_{it}}{v_t} \right)^2$$

Equation 11: Herfindahl-index

5. Exemplary Model Computation

5.1 Parameters Constellations

In order to obtain data about the two research questions, we computed a small instance of the model. A distinction into two different environments was made:

1. **optimistic** environment with small ε,
2. **pessimistic** environment with ε closely to one.

Every environment was computed with 20 actors of different sizes in a ratio analogous to the real German market structure. The simulation was run for 50 periods. The cost parameters were equally distributed within the following ranges, while the total economic profit was fixed to v_t=100 in every period:

Actor’s size:	large	medium	small
c_i^d upper border	5	3	1
c_i^d lower border	2	0.5	0

Table 5: Monetary parameters

[2] If only one innovator finds an innovation in a period the concentration index takes the maximal value of 1, while it becomes minimal (concentration index of 1/I) if every actor finds the innovation.

The costs for the patent process c^p are negligible in such a small scenario, because even if they are as unrealistically high as the maximal development costs of large companies and each company would find the innovation, each of them would try to get the patent. c^p comes into account, when more realistic market sizes will be simulated.

The probability parameters are equal in the different constellations (except ε) and constant in time. The probability parameters are:

Constant Probability Parameters		
Reducant by patent protection	e	0.85; 0,.999
Weight of prior development costs	w_d	0.9
Weight of prior successful innovations	w_x	0.9
Relative weight of development costs	a	0.5
Relative weight of successful innovations	b	0.5
Market difficulty	M	1.0

Table 6: Probability parameters

5.2 Results

Optimistic Environment (ε=0.85)

In all of the following diagrams the differing results of both scenarios - with and without patenting possibility - are shown.

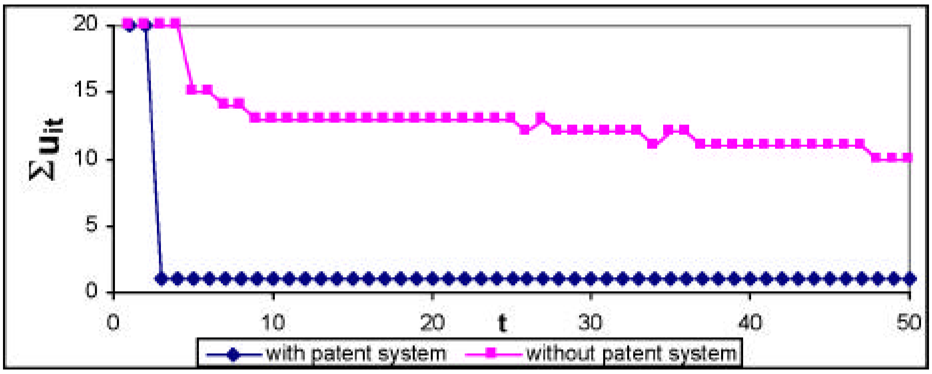

Figure 5: Sum of innovation activities

Figure 5 shows how many actors spent development costs in the several periods. In the first two periods all actors took efforts. In the first period nobody found an innovation, but in the second generation four actors found it. In this case all actors took part in the patent race which finally was won by actor 12. The impact of this patent on the innovation activities of the remaining actors was so enormous, that in future generations nobody else spent development costs. Without patents noticeably more actors invested in development activities.

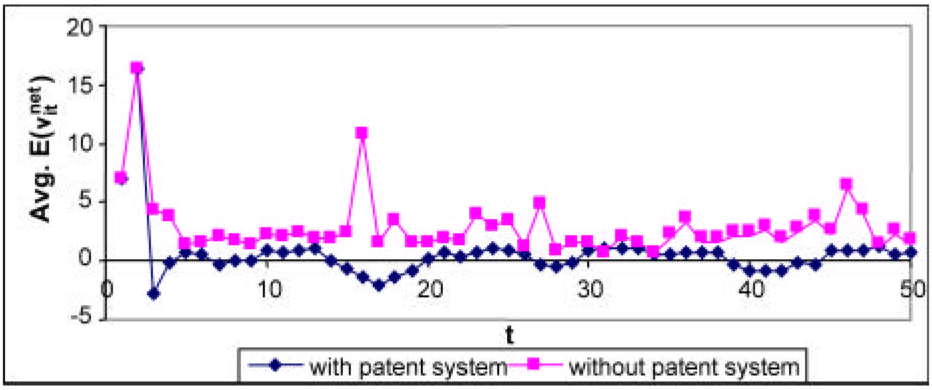

Figure 6: Average of expectation

An interesting result is that after a few generations with increasing innovation rates the average expectation decreases. This happens because of the estimator for $E\left[\sum_{i=1}^{I} x_{it}\right]$.

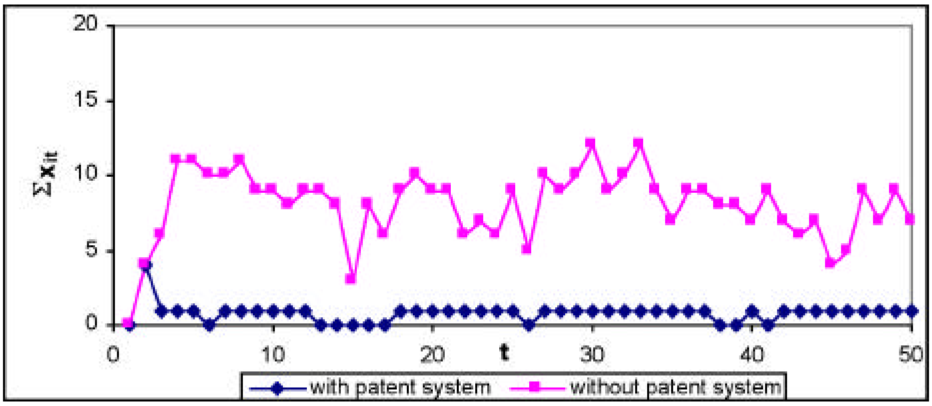

Figure 7: Found innovations

To evaluate our first question we simply counted all periods with innovations. In every snapshot under this constellation the scenario without patents had a significant higher rate of innovations.

Macroeconomic results	With patents	Without patents
Sum of periods with innovation	39	48

Table 7: Innovations with and without patents

To get an overview of the incentive situation in both "worlds" we calculated the average expectation of the actor's decision function (equation 7) over all actors. In figure 6 it can be seen that the average expectation was always higher in the scenario without patents.

The second main question was answered by the calculation of the Herfindahl-index. The endemic propensity to monopolize for the scenario with patents was confirmed. One actor won the patent race in period 1, after which he was the only innovator in all periods. The missing points represent periods in which he didn't find the innovation. In the environment with patent system we measured an inter-temporal Herfindahl–coefficient *HFI*, which represents the distribution of the several monopolies in time on the different actors. In this case was *HFI*=1, which means, that every monopoly was held by the same innovator.

Pessimistic Environment (ε=0.999)

In this environment both scenarios show almost similar results. The two peaks in periods 28 and 31 (figure 8) result from a an optimistic estimator in these periods. This is because in period 27 only one and in period 30 only three actors found an innovation (see figure 10). This relation can also be seen in figure 9, where the average expectations are rather high in periods 28 and 31.

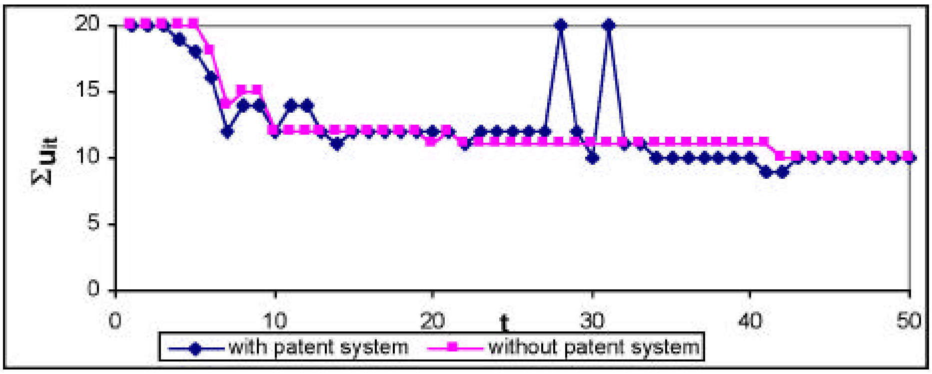

Figure 8: Sum of innovation activities

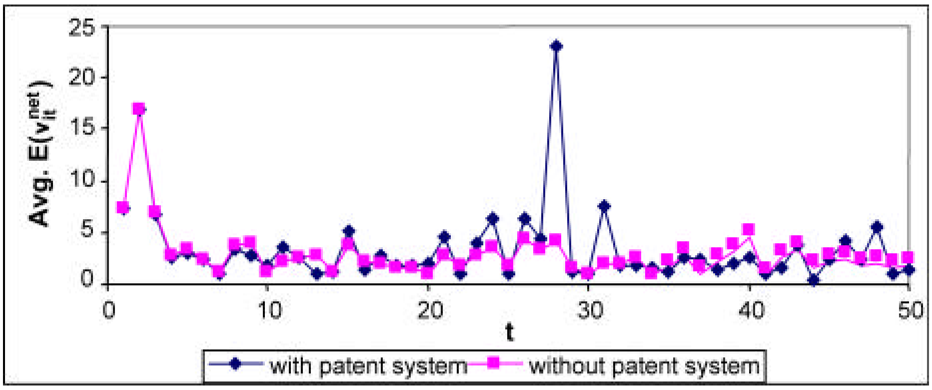

Figure 9: Average of expectation

Most innovations were found in period 6 with 13 resp. 12 innovations. The oscillations in this figure result from the nature of the probability function.

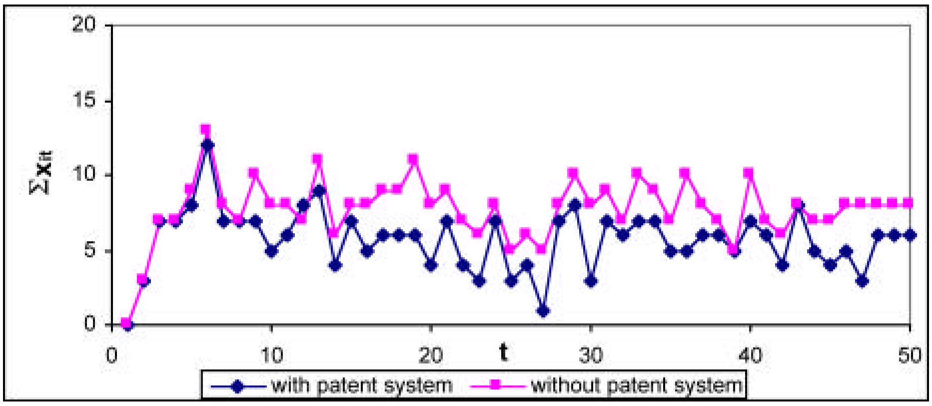

Figure 10: Found innovations

It is remarkable that if the protection strength of the patent is rather small (ε nearly 1), marginally more innovations will be found.

Macroeconomic results	With patents	Without patents
Sum of periods with innovation	49	48

Table 8: Innovation with and without patents

The Herfindahl-coefficient is one in every period, which means that like before, anytime the innovators competed for a patent because of the small market size. Contrary to the optimistic environment the inter-temporal Herfindahl-index was only 0.1112, denoting, that the patent winner changed often over time.

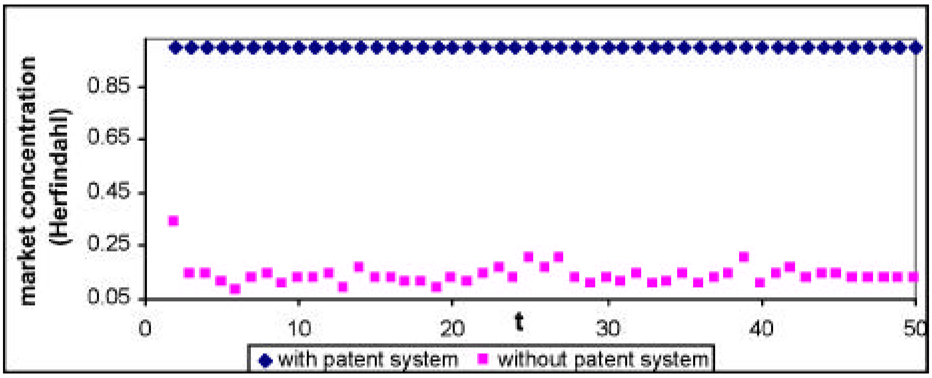

Figure 11: Herfindahl-index

6. Conclusion and Further Research

In this paper the impact of software patents on innovation success of software developers was analyzed with a bipartite model for comparing environments with and without a legal patent system. Software development could be basically characterized by five characteristics decisive for the question of patenting and its consequences: *Sequentiality*, *complementarity*, utilization availability of *open code*, the necessity to ensure *interoperability*, *as well as* the *digi-*

tal goods character. Based on these assumptions the model encompasses the factors influencing innovation success. We identified two key factors, taking effect upon the next three periods, the development costs and the existence of previous innovations. In the patent scenario the patent itself will have an additional effect. From the patent owner's perspective, we distinguished between two different environments, namely optimistic and pessimistic. Optimistic means that the impact of patent protection is very high, i.e. that the other actors not being the patent owner have smaller innovation probabilities in future generations ($\varepsilon \leq 0.9$). In the pessimistic environment ε is nearly one. Selected snapshots of exemplary simulations of small model instances showed that strong patent protection circumvented technical progress from a macroeconomic perspective. Moreover, in the long run only one actor (monopolist) dominated the market. Reducing the protection strength (pessimistic environment) resulted in partially contrary effects.

In our next steps we have to test the parameterization by simulating bigger instances of the model, integrating sensitivity analyses, and by reflecting the results against empirical observations. The actors' development costs values could be endorsed, to get more valuable findings about the incentive level of the members of the software industry. Further incentive potentials of patents have to be evaluated and to be integrated into the model and into the game theoretical examinations, which at least have to be augmented with a nondeterministic information base. Based on this, the model could be used as framework to make normative statements, determining the necessity of a patent system or evaluating the optimal length of patent protection subject to the particular cost structures of the software market.

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