Trader-Supported Information Markets - a Simulation Study

Michael Christoffel[1], Thorwald Franke[2], Stefan Kotkamp[3]

[1] Fakultät für Informatik, Universität Karlsruhe, Postfach 6980
D-76128 Karlsruhe, Germany
christof@ira.uka.de

[2] Deutsche Börse Systems AG
D-60485 Frankfurt am Main, Germany
thorwald_franke@exchange.de

[3] Fakultät für Wirtschaftswissenschaften, Universität Karlsruhe, Postfach 6980
D-76128 Karlsruhe, Germany
stefan.kotkamp@wiwi.uni-karlsruhe.de

Abstract. The modern society depends on the provision and distribution of information. We observe the development of world-wide information markets. Traders play an important role in these markets, as they bring together supply and demand. In this paper, we describe a simulation study about mechanisms and rules in information markets under special consideration of the role of traders. The usefulness of simulation for market analysis is shown in selected experiments.

1 Introduction

The modern society depends on the provision and distribution of information. The work of scientists, economists, politicians, educators, and others is affected by the steady supply with up-to-date information. Hence, we observe the evolution of word-wide information markets, where the value of a piece of information is determined by the law of supply and demand. We can expect that electronic trade will become dominant in these modern markets [1]. Since information goods can not only be digitized easily, but also edited and distributed electronically via the Internet, they are particularly well-suited candidates for electronic publication and commerce.

Information markets have some special features that distinguish them from traditional markets: the unequal distribution of cost, the possibility of cheap and maybe unauthorized copies and manipulations, the central role of quality of service, and the importance of services in addition to the pure delivery. A good general introduction into information markets can be found in [2], a more theoretical approach in [3]. An overview on pricing strategies for information goods is contained in [4] and [5].

In traditional markets intermediaries play an important role. There are indications that this will remain true for electronic markets [6]. Intermediaries are market participants other than customers and providers, which facilitate, aggregate, mediate, ensure trust, or provide market information. Information intermediaries are necessary to remedy one of the greatest problems that arise from the new richness of information providers, namely information overload. Customers are often not able to find and to compare suitable providers, and providers can not reach their customers by marketing. One such class are traders.

A simple and general definition of a trader can be found in [7]: “A trader is a third party object that enables the linking of clients and servers in a distributed system.” Transferred to the market scenario, we can define: A trader is a market object that brings together supply and demand. [8] gives a general overview on trading in information markets and communities of agents.

In this paper, we present a study on the rules and mechanisms in an open, dynamic, heterogeneous, and distributed information market, using the method of simulation. Our focus of interest hereby is the effect of traders on this market. It is important that traders are market participants without special privileges. The scenario of an open market must be distinguished from auctions and stock markets with a monopoly position of the brokering service. We hope to show that simulation is more appropriate for still developing markets than a closed mathematical model or an empirical study.

The paper is organized as follows: In section 2 we introduce an earlier approach to a simulation-based analysis of trader-supported information markets. In section 3 we present our simulation model and explain our experiments. The major results of these experiments are summarized in section 4. In the subsequent sections we discuss some of the experiments in more detail: Section 5 contains experiments concerning basic market mechanisms, and section 6 contains experiments concerning the influence of traders. We conclude the paper with section 7.

2 Related Work

A theoretical approach to the analysis of traders and intermediaries in information markets can be found in [9]. An interesting simulative approach is by Kephart and Hanson from IBM Thomas J. Watson Research Center [10,11,12].

Kephart and Hanson modeled an information market using three agent types: sources, brokers, and consumers. Sources produce articles and offer them to brokers. Brokers purchase these articles and try to resell them to consumers. The decisions of consumers and brokers are based on price and utility functions. Kephart and Hanson also considered the market infrastructure and took into account communication and delivery costs. The focus of their work was on the profit maximization and strategies for the brokers.

The approach makes a number of unusual assumptions. Commerce transactions are triggered by the providers, and the role of the customers is limited to the decision whether to buy or not. However, in electronic trade commerce transactions are usually triggered by customers that declare their demand. Brokers act as middlemen, buying and reselling goods physically. This ignores a major advantage of electronic commerce, namely that there is no need for a delivery before the trade is complete. So intermediaries better act as mediators and facilitators, and not as middlemen.

Despite these inconsistencies and the preferential treatment of the intermediaries, it is an interesting approach, bringing some pioneering results:

- Competition between brokers leads to (cyclic) price wars. These price wars were harmful to both brokers and customers. In many cases, brokers were eliminated.
- Some brokers avoided competition and price wars by specializing and niche-finding.
- Specialization could also be observed without price wars. Brokers were able to increase their profit by specialization.

3 Simulation Model

In this section, we describe our own simulation model KASTIM (KArlsruhe Simulation of a Trader-supported Information Market). The model underlies a three-tiered structure of customers, providers, and traders, which are all part of the simulation. The task of the traders in this model is the mediation between customers and providers. However, customers and providers may also interact directly.

The simulation model supports many features that allow to estimate the developing information markets as close as possible:

- clear distinction between infrastructure, search, and product costs
- different charging models applicable between market participants
- influence of advertisement
- cooperation among traders
- quality of service attributes that can be used to describe the confidence with delivery ways and times, formats, ease of use, response times, etc.
- memory function and learning behavior of customers, providers, and traders
- migration and immigration of market participants

Of course, there are also simplifications in comparison with real markets. For instance, we do model product groups rather than single information products. Product availability is a measure for the supply of the providers in a product group.

While the benefit of traders and providers is equated with their profit, the benefit of a customer depends on several factors. The aggregation of the factors is expressed by a utility function:

$$\mathrm{utility} = \begin{cases} (1-\mathrm{costPriority})\mathrm{servFactor} + \mathrm{costPriority} \cdot \mathrm{costFactor}, & \text{if success} \\ -\mathrm{failFactor}, & \text{otherwise} \end{cases} \tag{1}$$

$$\mathrm{servFactor} = 1 - \sqrt{\frac{\sum_{i=1}^{\mathrm{numSAttr}} (\mathrm{expSAttr}_i - \mathrm{realSAttr}_i)^2}{\mathrm{numSAttr}}} \tag{2}$$

$$\mathrm{costFactor} = 1 - \frac{\mathrm{realSearchC} + \mathrm{realProdC} + (1-\mathrm{adAggr})\mathrm{realTradC} + \mathrm{realNetC}}{\mathrm{maxSearchC} + \mathrm{maxProdC} + \mathrm{maxTradC} + \mathrm{maxNetC}} \tag{3}$$

$$\mathrm{failFactor} = \frac{\mathrm{realSearchC} + \mathrm{realTradC} + \mathrm{realNetC}}{\mathrm{maxSearchC} + \mathrm{maxTradC} + \mathrm{maxNetC}} \tag{4}$$

In the above equations, costPriority denotes the priority of the customer for costs (i.e., low prices) as opposited to the quality of service (range [0,1]). numSAttr is the number of service attributes, $expSAttr_i$ and $realSAttr_i$ are the expected and the real value for the service attribute i (range [0,1]). Costs are composed from search cost, product cost (prices), trader cost, and network cost (infrastructure). E.g., realSearchC and maxSearchC are the real and maximal search cost. adAggr is the advertisement aggressiveness of a trader.

The complete algorithm contains several more parameters. For example, if the advertisement aggressiveness exceeds a limit individual for a customer, the customer feels annoyed, and the trader will be ignored.

In our model, we apply event-based simulation [13]. Each searching and buying action is triggered by the customer. Whether the customer buys a product or not depends on the offers and the cost. However, incurred search costs have always to be paid. When a customer develops the demand for a special product, he/she starts a search for this product. Either he/she asks known providers, or he/she contacts a trader. The relations between customers, providers, and traders are not fixed and can be changed at any time.

The experiences of the market participants plays an important role, too. All participants hold data about other participants. For example, the decision whether a customer uses the services of a trader or not and which trader he/she selects depends on the utility the customer received from the trader in previous queries (but there is also a curiosity factor that induces the customer to test new traders or providers).

In order to enable the market participants to optimize their strategies, we have introduced a 'trial and error' behavior. Participants make slight changes to strategic variables at random and observe the change of the values that are to be optimized. For example, a provider may vary stocks and prices to optimize its profit.

The simulation model has been implemented under Java 2. The experiments were executed on a Unix workstation with a 296MHz 13,1 SPECInt processor and 128 MB RAM. A simulation run with 4 customers, 20 providers, and 4 traders over 1300000 units of time took about 7 minutes of computing time.

4 Summary of Results

We have carried out 16 different experiments with the KASTIM system until now, each encompassing several individual simulation runs. We come to the following major results:

- General principles of information markets as forecast by the theory or already shown in other experiments, such as price wars, niche-finding, and the continuous dynamism of the market, can be confirmed.
- Competition and price wars between providers can be harmful for the customer if this leads to a reduction of the product availability.
- Competition and price wars between traders have less influence on the customers, because disadvantages by fighting traders can be compensated.
- The installation of trading services in an information market leads to a clear and permanent increase of the utility to the customers.

- The specialization of providers decreases the profit of the traders, since customers do not have to rely on the help of the traders if they already know a specialist for their special demand.
- Traders profit from market dynamism, because their market knowledge becomes more valuable.
- Traders profit from a steady renewal of the customer clientele, because customers participating in the market for a longer time learn from previous queries about the market and decreasingly need the help of trader.
- Unsystematic cooperation between traders has no effect.
- The needs of customers that give priority to cost and those that give priority to services are completely different. Traders can benefit from this knowledge by specialization.
- For a provider, it is sufficient to register with only one trader. However, providers can profit from registering at more than one trader if the customers give priority to services rather than to cost.

In the following sections, we go into more detail on some selected experiments.

5 Basic Market Mechanisms

In this section, we describe two experiments about two basic market mechanisms: competition and specialization among providers.

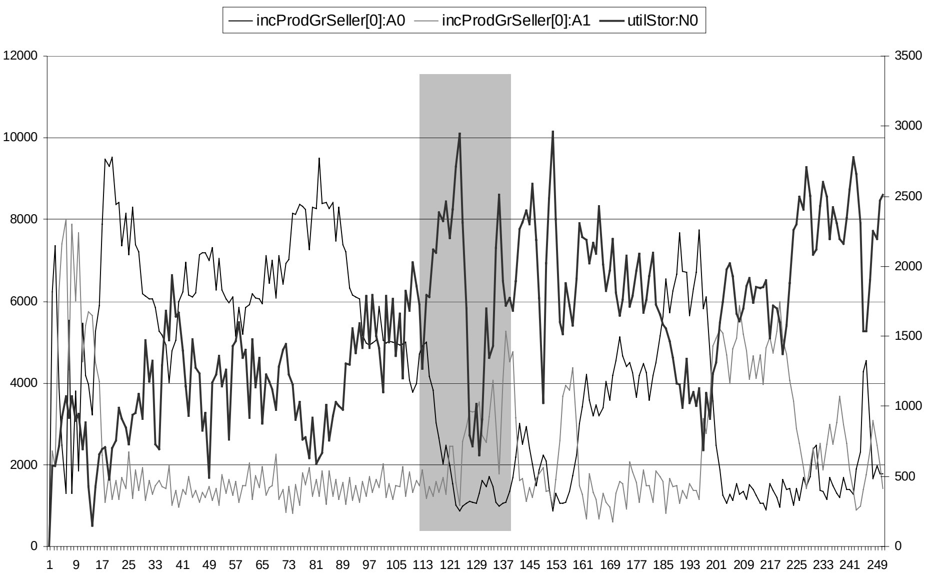

Fig. 1. An experiment to investigate competition between two providers. The figure shows the development of the income of the two providers (incProdGrSeller[0]:A0 and incProdGrSeller[0]:A1) and the utility of the customer (utilStor:N0) over the time

In order to investigate competition, we simulated a market with only 1 customer active at any time, 2 providers and no traders over 300000 units of time. Both providers are set up identically, and they offer the same single product group. From the customer's point of view, they only differ in their search and product costs

Figure 1 shows the development of the income of the two providers. The dynamism of the curves is caused by the steady movement of prices (and, as a consequence, sales). Measurements confirm that there are price wars between the providers, as both try to undercut each other continuously in order to achieve the market leadership (and raise the prices afterwards). Price wars affect both product and search costs.

The utility to the customer is also displayed in Figure 1. Here we can observe an interesting phenomenon (best visible in the marked detail): Before market leadership changes, the utility raises since prices fall, but then the utility goes down rapidly, although prices are low. An explanation can be found when we observe the development of the number of failed queries. The price wars led to an increase of the failed queries. This indicates that the customer was not able to find the demanded goods and could not benefit from the low prices. Indeed, the measurements show a reduction of the product availability of both providers, indicating a reduction of the stock. It is quite natural that the defeated provider reduces stock, because it sells less. The winning provider has also reasons to reduce stock, because its product prices are so low that it has to reduce stock in order to save storage cost. Another reason is that it sells so much that the falling product availability does not matter.

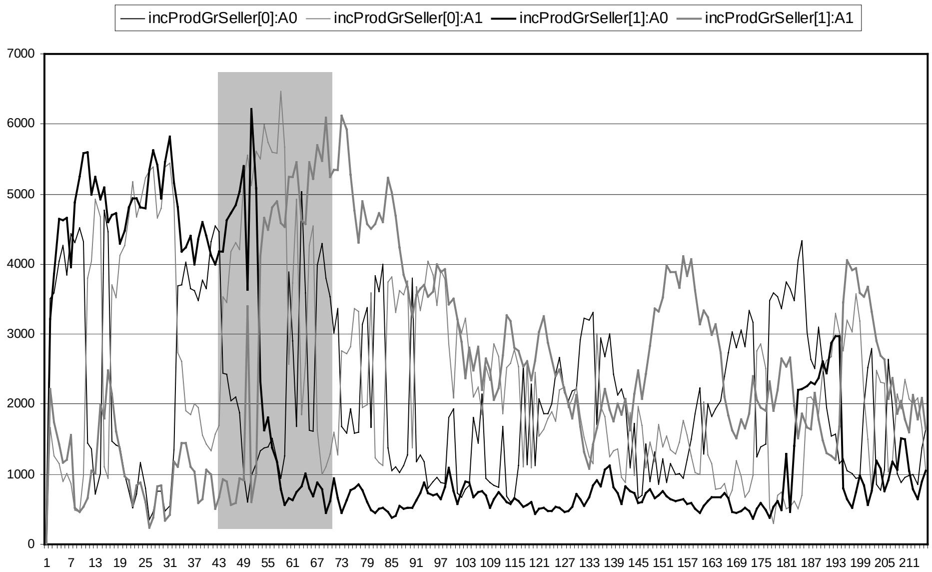

Fig. 2. An experiment to investigate specialization between two providers. The figure shows the development of the income of the two providers in product group 0 (incProdGrSeller[0}:A0 and incProdGrSeller[0]:A1) and in product group 1 (incProdGrSeller[1]:A0 and incProdGrSeller[1]:A1)

With the next experiment we illustrate the phenomenon of product specialization. As a significant difference to the previous experiment, there are now two product groups. The other parameters are 2 customers, 2 providers, no traders over 300000 units of time. Figure 2 shows the income of both providers realized in the two product groups. The most interesting detail is marked here, too. We can see that before time point 49 (49000 units of time), provider 0 has a clear leadership in product group 1, and provider 1 has a clear leadership in product group 0. So we can confirm the specialization of the providers.

However, market niches do not remain unchallenged. After measure point 49 provider 2 successfully conquers market leadership in product group 1. Provider 0 tries to switch to product group 0, but the attempt to achieve a dominant position does not succeed. Measurements show the effect of market niches in the product availability, too. The market leader in this product group has a product availability of up to 100%, whereas the other provider reduces stock under 50% (however, it does not give up the product group completely). Simulation runs with 16 providers (and 4 product groups) show an oligopoly of a few providers rather than the dominance of one provider.

6 The Role of Traders

So far we presented baseline experiments with no intermediaries. We now introduce a second set of experiments that include traders. We are focussing on the value of traders for the customer, the influence of the number of providers and of the total number of customers on the trader's profit.

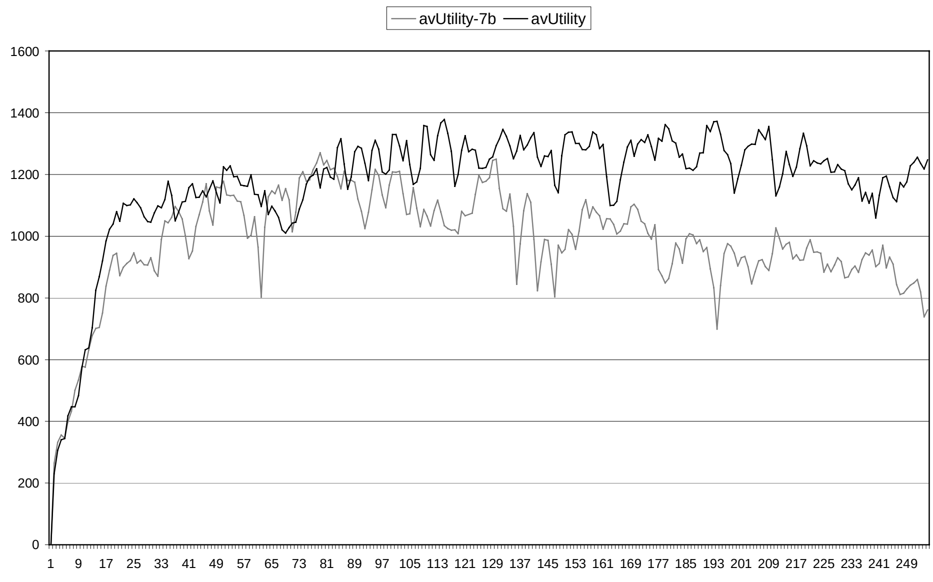

Fig. 3. An experiment to investigate the utility of traders to the customers. The figure shows the development of the average utility of the customers with traders (avUtility) and without traders (avUtility-7b)

The first question was whether customer benefit from traders or not. We compared the average utility to a customer in two markets: One with no traders, another one with 10 traders. The other parameters in both markets were 10 customers, 20 providers, and 5110000 units of time. As we can see from Figure 3, the average utility of a customer in the market with traders is approximately 19% higher than in the market without traders.

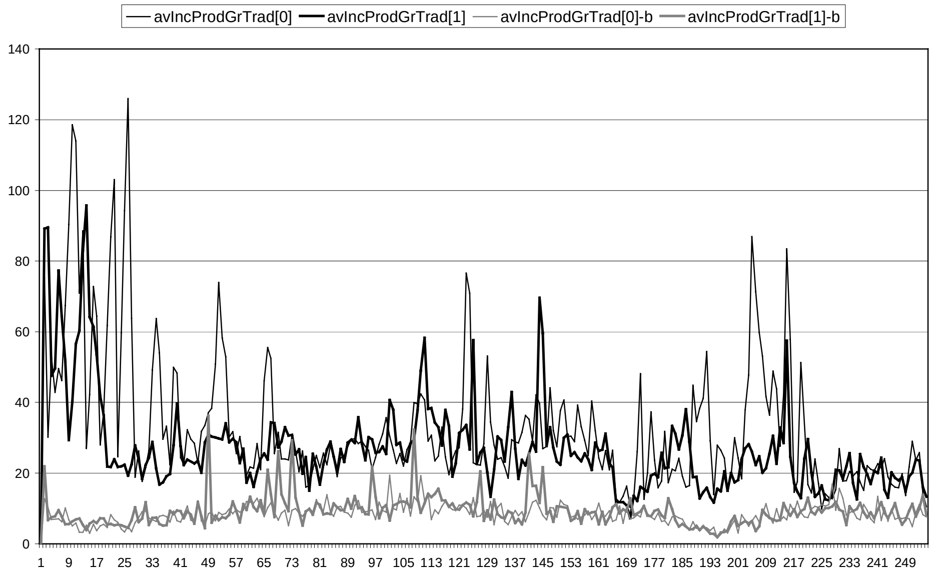

Fig. 4. An experiment to investigate the influence of the number of providers in a market on the profit of the trader. The figure shows the development of the average income of the traders in two product groups in a market with 4 providers (avIncProdGrTrad[0] and avIncProdGrTrad[1]) in a market with 24 providers (avIncProdGrTrad[0]-b and avIncProdGrTrad[1]-b)

In order to observe the influence of the number of providers on the trader profit, we simulated two markets, one with 4 providers, another one with 24 providers. The other parameters were 4 customers, 4 traders, and 1800000 units of time. In Figure 4 we see - on first glance surprising - that the trader's profit is higher in the smaller market. The explanation can be found in the specialization of the providers. Because of the high level of competition in the market with 20 providers, the providers concentrated on one or few product groups (niche-finding). So customers could find experts among the providers and needed the help of a trader less often.

In the next experiment we investigated the influence of the total number of customers on the trader profit. We simulated two markets: In the first market customers stay the same over the simulation run, and in the second market customers leave the market and are replaced by new customer (randomly, one customer every 500 units of time). The parameters in both simulations were 4 customers, 24 providers, and 4 traders over 1344000 units of time. Figure 5 shows the development of the average profit of the traders in both markets. The profit of the trader is approximately 37% higher in the market where customers are changing. So traders profit from a higher number of customers. The explanation lies in the memory of the customers. During the simulation run, they gain their own knowledge about the market. However, the dynamism of the market prevents traders from becoming superfluous, even if the customers do not change.

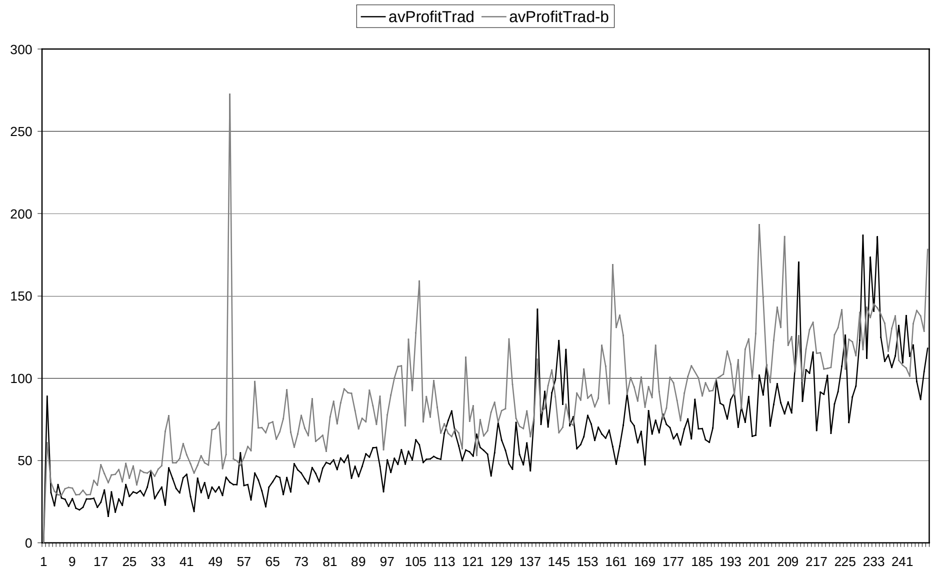

Fig. 5. An experiment to investigate the influence of the total number of customers in a market on the profit of the trader. The figure shows the development of the average profit of the traders in a market where customers are not replaced (avProfitTrad) and in a market where they are replaced (avProfitTrad-b)

7 Conclusion

In this paper, we presented a simulation study about the rules and mechanisms in an open information market under the special consideration of the role of traders. The aim of this study was to show how simulation can help in the analysis of market mechanisms, especially when these markets are in the phase of evolution. The understanding of the market mechanisms is essential when building the necessary information technology infrastructure. The consideration that market participants in new electronic markets will often be autonomous software agents rather than human beings even increases the importance of these questions.

The correspondence of our observations with the theory of the information market and the results of the study of Kephart and Hanson seems to confirm the correctness of our approach. This is not only true for obvious observations like dynamism and competition. Complex and somehow surprising phenomena could be observed, too. For example, the observation that price wars may harm customers has also been reported by Kephart and Hanson. We have found an explanation for this in the reduction of product availability. Basic strategies, such as differentiation and cost leadership, could also be confirmed. An important result of our study is that traders are always worth their price if the market is sufficiently dynamic and heterogeneous. This result has been forecasted by Rose [9].

We plan to continue our work on information markets. We plan new, more thorough experiments, leading to a more precise description of the dependencies of the variables, and also longer simulation runs, showing the success of strategies on a longer time-scale. Extensions to the model are planned to include cooperations, negotiations, and trust-building measures. The implementation of an infrastructure for a special market [14] will produce a basis for experiments under realistic conditions.

References

1. Bakos, Y.: Towards Friction-Free Markets: The Emerging Role of Electronic Marketplaces on the Internet. In: Communications of the ACM, 41(8) (1998)
2. Shapiro, C., Varian, H.: Information Rules (1999)
3. Arunkundram, R., Bakos, Y.: Search Characteristics and Equilibrium in Internet-based Electronic Marketplaces. In: Proceedings of the 9th Workshop on Information Systems and Economics, Atlanta (1997)
4. Kotkamp, S.: Pricing Strategies for Information Products. In: Deutsche Bank - Inhouse Consulting Manager, 3 (2000)
5. Bakos, Y., Brynjolfsson, E.: Aggregation and Disaggregation of Information Goods: Implications for Bundling, Site Licensing and Micropayment Systems. In: Proceedings of Internet Publishing and Beyond: The Economics of Digital Information and Intellectual Property, Cambridge (1999)
6. Bailey, J., Bakos, Y.: An Exploratory Study of the Emerging Role of Electronic Intermediaries. In: International Journal of Electronic Commerce, 1(3) (1997)
7. Bearman, M.: ODP-Trader. In: Proceedings of the International Conference on Open Distributed Processing, Berlin (1993)
8. Klusch, M.: Agent-Mediated Trading: Intelligent Agents and E-Business. In: Journal on Data and Knowledge Engineering, Special Issue on Intelligent Information Integration, 36(3) (2001)
9. Rose, F.: The Economics, Concepts, and Design of Information Intermediaries (1999)
10. Kephart, J., Hanson, J., Levine, D., Grosof, B., Sairamesh, J., Segal, R., White, S.: Dynamics of an Information-Filtering Economy. In: Proceeings of the 2nd International Workshop on Cooperative Information Agents, Paris (1998)
11. Kephart, J., Hanson, J., Sairamesh, J.: Price War Dynamics in a Free-Market Economy of Software Agents. In: Proceedings of the 6th International Conference of Artificial Life, Los Angeles (1998)
12. Hanson, J., Kephart, J.: Spontaneous Specialization in a Free-Market Economy of Agents. In: Proceedings of the Workshop on Artificial Societies and Computational Markets, Minneapolis/St. Paul (1998)
13. Zeigler, B.: Theory of Modeling and Simulation (1985)
14. Christoffel, M., Pulkowski, S., Schmitt, B., Lockemann, P.: Electronic Markets: The Roadmap for University Libraries and their Members to survive in the Information Jungle. In: Sigmod Record Special 27(4) (1998)