The Impact of InfoCenters on E-Marketplaces

A thesis submitted in fulfillment
of the requirements for the degree of
Master of Science

by

Itai Yarom

Supervised by
Jeffery S. Rosenschein

Computer Science Department
The Hebrew University of Jerusalem
Jerusalem , Israel

December 5, 2001

Acknowledgments

I would like to thank my tutor Prof. Jeffrey S. Rosenschein and Dr. Claudia V. Goldman for the invaluable support and help they rendered for me throughout my work. I am also thankful to my wife, Michal, who encorauge me to continue and without whom this project would never has been completed.

Contents

Chapter 1

Introduction

The Internet provides access to a wide range of information, and enables people to communicate without the limitations of physical distance. The Internet contains a large amount of information that can be obtained without charge. However, finding the information you need, with a high degree of confidence that the information is correct, can be a tedious job. Therefore, we believe that people will be willing to pay in order to obtain the information for which they are looking. Services that provide “information assurance”, and seller ratings, will enable buyers to validate the correctness of the information they are buying and the seller’s service quality. Today, services that sell information over the Web are starting to emerge, like Web sites that offer analyst reports on various subjects (e.g., Gartner [gar] and IDC [IDC]). We believe that in the coming years there will be even more services that will sell information over the Web.

One of the most common ways to trade over the Web is by using Electronic Marketplaces (i.e., e-markets). E-markets broaden the opportunities for humans and autonomous agents to trade, for example by allowing them to access stores that are not necessarily physically accessible. In addition, E-markets allow people to exchange pieces of information. Users can buy articles without being obliged to buy a whole journal; users can obtain news adapted to their personal interests without buying the whole newspaper. For these reasons and others, we believe that e-markets will be used to trade information over the Web.

The possibility of treating information as a truly tradable commodity generates new questions that need to be examined. Pricing policies could be standardized to quantify basic units of information. New kinds of transactions can be developed that are not common for classical (physical) commodities. Eventually, operators can be applied to these pieces of information, creating new products based upon the buyers’ requests or as new suggestions to those buyers.

This thesis focuses on information as a commodity traded in e-markets. The basic idea of information markets is not new; pieces of information are already being traded in existing systems (e.g., [KGMP97]). Thus, automated tools to handle these pieces of information, as we will propose in this thesis, are becoming more necessary.

Information management and commerce must deal with questions such as how different pieces of information will be handled, and how their prices will be calculated. Shall we enable the customer to have full information about available information products before carrying out a transaction? How can a software agent assist a user in building new information products out of the basic information building blocks existing in his data storage?

The information e-markets will enable billions of buyers and sellers to trade. Using the assistance of software agents in those e-markets will enable buyers and sellers to handle large amount of information, which humans will not succeed in handling on their own. Furthermore, the low communication costs will enable buyers and sellers to explore the different information products and services that are being offered in the information e-market. Therefore, we believe that humans will be assisted by autonomous agents in carrying out various tasks, including:

1. Shopbot agents [GK99] — which finds the sellers that offer the desired information product with the lowest price.

2. Pricebot agents [GK99] — which helps the sellers to set prices for the information products they offer. They can explore the e-market, or use the services of a Pricebot agent for obtaining the prices of other sellers, and by using this information they can set the price.

3. Broker agents [DSW97] — which will help to match buyers that are interested in certain information to sellers that offer that information.

Though we can easily understand how software agents can assist buyers and sellers, the role of the middle-agent might be obsolete in e-markets. On the one hand, buyers can approach sellers without the assistance of a middle-agent. On the other hand, the middle-agent will have new roles in e-markets, for example, helping sellers to increase their profit in a competitive market. In such a market, the low communication costs enable buyers and sellers to be informed about other sellers' prices. In that way, buyers will be able to find sellers with the lowest prices. This may create a price war between sellers over information prices, leading sellers to sell the information at its marginal cost [Tir88, Var80, WS79].

Sellers will have to offer added value to their information in order to remain profitable. They can be assisted by a middle-agent, which can approach buyers, sellers and other agents that provide information services. Using those capabilities, the middle-agents can offer information that is needed by buyers and no seller is offering yet. In that way, the middle-agent will help sellers to offer information that is unique, and therefore to avoid price wars. By doing so, sellers will be able to sell the information with prices that are higher than their marginal costs. In other words, the sellers will be able to become profitable.

Middle-Agents can offer services needed both by the sellers and the buyers. Services, as presented by Bakos et al. [BB97], can include aggregation and disaggregation of information, providing trust, and providing inter-organization information. In this research, we focus on information that can be dealt with in e-markets. In particular, we have developed the notion of InfoCenters, automated (middle) agents that have wide accessibility to information products, as well as to manipulated data.

An InfoCenter is a software agent that interacts with information suppliers (i.e., sellers), information consumers (i.e., buyers), and Information Service Providers (InfoSPs) that can be automated agents or humans. Therefore, an InfoCenter agent can buy and sell information products. Moreover, it can obtain manipulated information from the InfoSPs. The InfoSP agent enables services such as changing the encoding of information (e.g., JPEG to GIF), adapting the presentation to different platforms (e.g., desktop or palmtop), updating information, summarizing it, or combining pieces of information. InfoCenters act as information intermediaries, and can reside, for example, in a library, at a portal Web site, or at a site that answers user questions.

The marketplace investigated in this work contains InfoCenter agents, InfoSPs, information consumers (buyers), and information suppliers (sellers). Three models of trading interactions introduce the motivation for the creation of InfoCenter agents. Then, results from simulations run with different behaviors of InfoCenter agents are presented.

We focus on the impact that InfoCenters have on an e-market when they sell new information products resulting from applying operators on basic units of information. We shall conclude by presenting the effects of different artificial intelligence (AI) techniques, such as planning and coordination, on the InfoCenter decision process. These include: 1) using planning in order to choose wisely which InfoSPs' services to use, 2) using communication protocols when approaching buyers in order to understand their needs, and 3) using decision making algorithms for choosing what information to offer.

Chapter 2 gives an overview of recent work on information e-marketplaces, and sets the stage for a detailed investigation of the dynamics of InfoCenter Agents (i.e., InfoCenters) in Chapter 3. In Chapter 4, we present experiments that we carried out, and analyze the results. We shall conclude in Chapter 5 with a summary and conclusion, and discuss future work in Chapter 6.

Chapter 2

Overview

2.1 E-marketplace

A marketplace is a place where sellers and buyers can trade commodities, which can be books, CDs, articles or magazines. Electronic marketplaces (E-markets) are marketplaces that exist on the Web. Buyers and sellers in E-markets can be humans or autonomous agents. Today at almost every commercial site, like Yahoo, Sony, Microsoft and Intel, you can find an E-marketplace. There are Web sites that specialize in E-markets, like eBay [eBa].

Due to the popularity of E-markets, we believe that information E-markets will emerge as a way to obtain information. Information does not have to have a physical existence, and it can be presented in digital format. For example, printed information can be represented in PDF, Postscript (PS), eBook or ePaper formats, audio information in WAV or MP3 formats, and video information in DVD, streaming video or AVI formats. Since information has no physical existence, it is easier to duplicate it. Therefore, special care for copyright protection should be considered. The copyright issue has been addressed by several researches (e.g., [KGMP97]), but none have offered a compelling solution yet. In this study, we assume that the marketplace will handle the copyright issue somehow, and we do not address this issue.

E-markets can use different mechanisms for buying and selling. One of the more common mechanisms is an auction. In a classic auction, sellers place offers for a product or a service and buyers place bids of how much they willing to pay for that product or service. The highest bid will win the product or the service, and the buyer will pay to the seller the bid price. An example of Information E-market that use the auction mechanism is the University of Michigan Digital Library (UDML) [PDB98]. The UDML is an open e-market of information goods where agents can offer information and services. Those agents can trade for information and services that are traded outside the UDML and offer them in the UDML e-market. That behavior is similar to the behavior of intermediaries between the UDML customers and the services available outside the UDML market. We will specify in more detail the role of intermediaries in Section 2.3.

Anther auction type that is being used both in the physical world and in the electronic one is the Continuous Double Auction (CDA). In CDA, buyers place requests and sellers place offers for services. When there is a request that can be fulfilled by a certain service, then the marketplace approaches the buyer and the sellers and performs the transaction. CDA markets are used in stock markets like NASDAQ and NICE. Information e-markets that use the CDA mechanism were offered by Das et al. [DHKT01]. In this market, they explore the market behavior and buyers' and sellers' profits, when buyers and sellers can be humans or autonomous agents. Though this mechanism can be used in e-markets with both humans and autonomous agents, it might have problems in being used by billions of users. In those cases, it might be hard to track a matching transaction out of the billions that are possible.

There are other types of auctions, like reverse auctions (where the buyer places a request in the marketplace, and sellers place bids of the service they offer for that request). There are also other ways to trade, like using negotiation. In the negotiation mechanism, buyers and sellers can negotiate over the price of the commodities. Chavez et al. [cM96] presented the Kasbah, a marketplace where buyers and sellers can negotiate over information products. This mechanism is one step further from the classified ads marketplace, because this mechanism helps in finding the information pieces and in buying them as well. The disadvantage of negotiation is the time it may take to close a deal.

There are additional ways to trade information, but the most common pricing method both in the physical world and in the electronic world is the post pricing method. In this method, the sellers post their prices and the buyers can buy the commodity at that price or not. Dynamic Post Pricing (DPP), offered by Kephart et al. [KHG00], is similar to the post pricing method, but in this method the sellers can change prices at every given time.

We expect that the information marketplace will use the posted pricing mechanism. This is because, in an auction, the buyers will have to wait until the auction has ended before they will be able to obtain the commodity they bid for. This can take minutes, hours, or even days. Buyers of physical items, in general, will be willing to wait for longer periods of time for the product. When information is involved, time may become an important factor. For example, a person wants to choose a movie to see tonight. This person wants to use the movie reviews in order to find an interesting film. If the person will receive the reviews after several days, it will be too late. Furthermore, if that person will use an agent that will obtain the reviews for him, then that person will generally expect that the agent will do it quickly.

2.2 Agents in E-markets

Buyers and sellers in E-markets can be represented by autonomous agents or by humans. Before agents will get permission to be completely autonomous, their owners need to be sure that the agents can be trusted. Agents have advantage over humans in that they can handle larger numbers of products, and they never get tired. Das et al. [DHKT01] compared the behavior of agents and humans in a CDA E-market. They performed several experiments, with markets that contained only humans, only agents and both agents and humans. Agents outperform humans in a market that contains both agents and humans. Agents in a market that contains only agents have similar behavior, compared to humans in a market that contains only humans. Therefore, it is not surprising that E-markets today contain different kinds of agents, and we expect that there will be more and more agents taking part in E-markets. Agents in e-marketplace can play different roles, including:

- Price comparison agents (i.e., ShopBot [GK99]) — an agent that helps buyers to find the seller with the lowest price.

- Auction bidder agents – an agent that places bids for buyers. Simple auction agents, like the one offered by the auction site eBay [eBa] help a buyer offer the minimal bid. More advanced auction agents are offered by Morise et al. in the SARDINE project [MRM00], which is a marketplace of airline flight tickets. This auction agent will consider other parameters in addition to price, like time between connection flights. The auction agents will enable the buyer to specify the weight of several already-defined parameters. Using this information, the auction agent will place bids for the best flight available.

- Broker agents [DSW97] — which help to match buyers that are interested in certain information to sellers that offer that information.

- Recommendation agents — agents that recommend products that buyers might be interested in. For example, at the Amazon Web site [Ama], there is a recommendation agent. The agent will create groups of buyers that have bought similar products. When a buyer is looking for a product, then the agent will offer the buyer other products that were purchased by similar buyers.

- Pricing agents (i.e., Pricebots [GK99]) — this agent helps sellers to set prices for the information commodities they offer. This agent can use various types of algorithms, and even use other agents like Shopbot in order to compare their prices to other sellers' prices.

There has been much work on how sellers can gain profit in a marketplace with competitive pressure [Tir88, Var80, WS79, SS82, BJ83, Dia71, HS96]. The costliness of finding the seller with the lowest price could enable sellers to impose prices higher than the marginal cost. In e-markets, low communication costs can remove this barrier. For example, if a person is looking for a CD of Santana, then this person can go to several stores to compare price. This can take about an hour or so and the saving will be about a dollar or two — not a significant profit for an hour of work. This person can search for this CD over the Web, by looking in several CD e-stores. This can take about ten minutes and the profit will be about a dollar, which is much better. But if this person will use a price comparison site, then in ten seconds that person will obtain prices of ten to twenty CD stores. For ten seconds of work it will compare more stores than before, and could buy the CD at a lower price. With this method, the profit is certainly worth the effort.

Therefore, the existence of Shopbot agents (i.e., comparison shopping price agents) in E-markets will create competitive pressure between sellers over the prices, and will drive prices to their marginal cost. Sellers, in order to gain some profit, will have to offer added-value to their products. One way is to offer information bundles [KF00, BB00]. In that way, a seller can offer a unique bundle of information and therefore sell it at a price which is higher than the marginal costs. This is because by selling information bundles, the seller sells unique information that other sellers do not offer. In our work, we enable additional information manipulation, including: changing the encoding of information (e.g., JPEG to GIF), adapting the presentation to different platforms (e.g., desktop or palmtop), updating information, summarizing it, or combining pieces of information. More details on information manipulation can be found at 3.3.1. All of the above can enable sellers, and in our case the InfoCenters, to create added-value for their information.

Finding the information bundles that will gain the highest profit is not a trivial task. As presented by Brooks et al. [BDD00], the process of finding the best niche can be a hard process that will cost the agent a significant amount of money. In order to enable the InfoCenters to handle this problem, we enable them to approach buyers in order to understand what information they are interested in. In that way, InfoCenters can offer information that has demand from buyers.

2.3 Middle-agents and Information Centers

Middle-agents, like middle-men, can help buyers and sellers in E-markets. The role of middle-agents (according to Decker et al. [DSW97]) is to help with the flow of information in E-markets. They defined three type of agents: 1) sellers or providers, 2) buyers or requesters, and 3) middle-agents. A middle-agent is defined as an agent that helps the flow of information in an E-market by dealing with the requests and the capabilities of other agents, and it is not a provider nor a requester agent. They distinguish between different kinds of middle-agents by considering the different levels of privacy that the middle-agent applies: 1) only the agent knows, 2) only the agent and the middle-agent know, and 3) all the agents know. This privacy model is used both for the capabilities of sellers and for the requests of buyers. Therefore, we potentially get nine types of middle-agents. They focus on three type of middle-agents, which are:

- Matchmaker or yellow-page agent — collects advertisements of capabilities of the sellers, and enables buyers to find the right seller for them. In this model, all agents are aware of the sellers' capabilities, but only buyers are aware of their requests.

- Black-board agent — collects requests from buyers in the market, and enables sellers to choose which requests they want to handle. In this model, all agents are aware of the buyers' requests, but only sellers are aware of their capabilities.

- Broker agent — which processes both. In other words, the broker agent collects requests of buyers and capabilities of sellers and matches between them. In this model, buyers and middle-agents are aware of the buyers' requests, and sellers and middle-agents are aware of sellers' requests.

In the evaluation of middle-agent performance, they consider 1) the efficiency of handling a request (i.e., response time), 2) what resources are used, 3) the vulnerability of the system to failures, and 4) the ability to quickly adapt changing preferences and capabilities. Information pieces did not have prices in the following models, and thus agents were not evaluated according to economic criteria (i.e., utility).

Bailey and Bakos [BB97] studied the roles of intermediaries in information e-marketplaces. They explored thirteen firms that participated in E-commerce activities. New roles for electronic intermediaries were found, including: aggregating and disaggregating information (e.g., aggregating several magazines into one information product or disaggregating magazines into separate articles), providing trust, and providing inter-organizational market information. In this thesis, we explore how manipulation of information (e.g., aggregating information) influences the information marketplace.

Intermediary agents in Bailey and Bakos' research behave like InfoCenter agents, because InfoCenters are middle-agents or intermediaries that have high accessibility to information and services. InfoCenters can manage digital libraries like the University of Michigan Digital Library (UDML) [PDB98] and the Stanford Digital Library [KGMP97]. In that sense, the library behaves like a center of information (i.e., an InfoCenter in our terms). The library interacts with information suppliers, like book and magazine publishers, for retrieving their information. The library has several payment options that it can use in order to obtain and supply information, like pay-per-view, subscription, sessions, shareware, and pre-paid vouchers. It offers its information to its customers that pay for this service. The library can interact with other libraries for obtaining information in their area of interest. In this thesis, the InfoCenter agent has the capabilities of the digital libraries with additional capabilities like manipulation of information.

Chapter 3

The model

3.1 InfoCenter Agents and InfoSPs

In this section, we motivate the placement of InfoCenter agents into information e-markets. Even though accessibility to information on the Internet is not constrained by physical distance, information intermediaries nevertheless appear to be beneficial. An InfoCenter agent is useful in three scenarios as described below:

- *When the InfoCenter agent already exists* — There are infrastructures that already exist and that contain "information centers", where InfoCenter agents' role as intermediaries is natural and direct — for example, in classical and digital libraries (e.g., the Stanford Digital Library Project [KGMP97]). The library buys information such as books, magazines and articles, and it serves its audience which pays for that information. Libraries already exist, and their services can be extended by adding InfoCenter agents that will interact with different information suppliers and consumers.

- *When buyers benefit from interacting with an InfoCenter agent* — E-marketplaces may be interested in extending the services they provide to their buyers, by adding assistance services. For example, an InfoCenter agent can help buyers by aggregating information (from different sources) that answers requests submitted by those buyers. In this case, the InfoCenter may need to interact with other software agents (e.g., agents who provide information services) to understand the question and to manipulate the different information elements so as to prepare the answer. The InfoCenter agent provides an obvious service to the buyer. The existence of such an InfoCenter agent "middleman" can also benefit sellers, because the InfoCenter agent can help them sell their information to buyers by customizing it. In other words, the InfoCenter is a "value-added" reseller of information. Of course, pricing strategies are needed to establish the relation between InfoCenter agents and the original sellers.

Another example is when a buyer is only interested in one piece of information and is not interested in a surrounding set of information (e.g., a buyer may be interested in acquiring an article but not the complete journal). InfoCenter agents can handle subscriptions to information suppliers and provide buyers with the specific information.

- *When sellers benefit from interacting with an InfoCenter agent* — Sellers may have various pieces of information that they want to sell, but not want to handle the task of finding buyers. In that case, they can use an InfoCenter that will buy information from them and find potential buyers. In that way, the InfoCenter provides a way to match (for example) experts, and buyers that are interested in the experts' knowledge. A similar approach was taken by Kamoon [Kam].

Figure 3.1 depicts an e-marketplace that includes buyers and sellers interacting with InfoCenter agents that can obtain manipulated information from InfoSP agents.

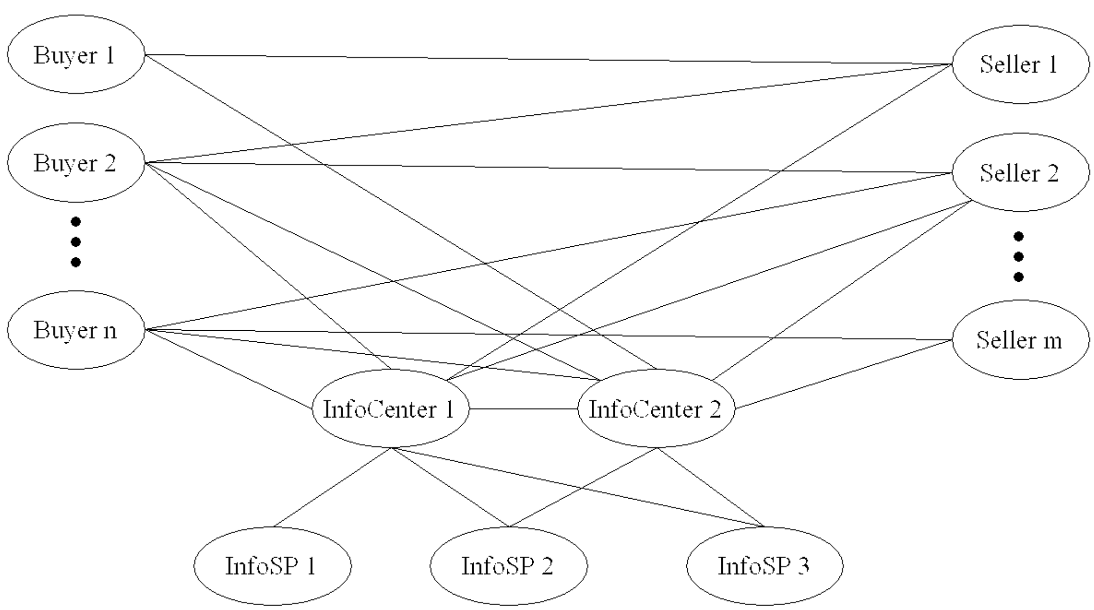

Figure 3.1: A basic e-marketplace including InfoCenter and InfoSP agents

3.2 The Model

Our study is based on the same marketplace model proposed by Kephart et al. [KHG00, KG99]. This marketplace contains commodities that are offered by S sellers, and which may be bought by any of the B buyers, assuming $B >> S$. Each buyer generates purchase orders at random times, at a rate of ρ_b, while each seller resets his price at random times, at a rate of ρ_s. The worth of a good to a buyer b is represented by the value V_b. The cost of production for a seller s is C_s.

Our framework extends the basic model [KHG00] by including InfoCenter agents and Information Service Provider (i.e., InfoSP) agents. InfoCenters are added to the basic market as intermediaries of information. These agents interact with information suppliers and consumers by buying and selling information. We will use the terms sellers and buyers only for the original information suppliers and end consumers. Though InfoCenter agents also buy and sell, we will refer to these agents solely as InfoCenters to avoid confusion.

The InfoSP agents are responsible for manipulating basic pieces of information. New commodities will eventually be built out of the existing commodities in the market. InfoCenter agents can approach InfoSPs to obtain new information after InfoSPs have manipulated it. It is important to approach the InfoSP services in a wise manner. First of all, the same manipulated information can be created using different information commodities and different InfoSPs' services. Choosing the best set of information commodities and InfoSPs' services may be a complicated job that requires planning. Second, new information commodities may decrease profit. That can occur when buyers prefer the new information commodity, but are not willing to pay more for it. In that way, the cost is higher since additional service was needed to produce it, but the price is the same.

Buyers can buy information products directly from regular sellers, and they can also buy them from the InfoCenters, taking advantage of the more sophisticated features of the latter. Regular sellers can sell information to the InfoCenters as well, regarding them as other interested buyers.

The goal of the InfoCenter is to profit, as a middleman, by using the marketplace entities in a smart way. Unlike a seller, the InfoCenter can selectively choose which commodities it wants to offer, and can use the InfoSPs to create new commodities that are not available in the market. Choosing which niche it wants to support can influence its profits. For example, if a certain commodity has a low profit margin, the InfoCenter can stop offering it. InfoCenters can also track the history of buyers' requests, and adapt their list of products accordingly (i.e., continue selling a newly created product that buyers keep demanding, or stop selling it).

Sellers are the basic information sources (i.e., we assume that sellers already hold information products). InfoCenters are agents that can buy information products from sellers and can sell it, potentially in a different form. In the more general model, InfoCenter agents can also buy information products from other InfoCenters. The InfoCenter agent can use any one of the following payment systems to pay for information sold by sellers:

- Full Price (FP) — The InfoCenter agent pays the list price for information it buys from sellers. This model of payment is reasonable if the InfoCenters can sell manipulated information. Otherwise, the InfoCenter will not have any incentive to buy and resell the same information, because then they will not have any added value from which to profit.
- Wholesale Price (WP) — The InfoCenter agent pays a reduced price if it buys a large quantity of information. In this case, the seller has to decide which discount method to use. We suggest three discount methods:
  - Discount Price — The seller gives a discount (e.g. 10%) of the current market price.
  - Average Price — The seller uses the average price of the information commodity. In that way, it guarantees generating some average profit.
  - Minimum Price — The seller offers the information at cost, plus a selling fee. Thus, although the average profit will be low (i.e., it will be the selling fee), sellers will have more opportunities to sell more information commodities, by offering them at a low price.
- Subscription Payment (SP) — The InfoCenter agent pays a subscription payment for the right to sell a certain quantity of information, and royalties on each information unit that it sells. If the royalties are equal to zero, then we get the WP payment as described above. The seller can use one of the discount methods described above, and in addition will have to determine the ratio between the subscription payment and the royalty payments (e.g., 80% of the price will be paid as subscription payment, and the remaining 20% will include royalty payments).

We tested two criteria for evaluating the effectiveness of the different configurations and algorithms. The first is **profit**. This criterion compares the profit obtained by InfoCenter agents, information suppliers, and consumers in all settings tested. Applying this criterion, we can learn whether sellers and buyers benefit from the existence of InfoCenters in e-markets where they exist. The second criterion is **stability of the marketplace**. A marketplace with frequent price changes can create unstable environments for buyers. The reason is that a commodity bought now may cost, for example, half the price or twice the price if the buyer waits. A marketplace with (relatively) stable prices is desirable, although care should be taken to avoid a monopolistic marketplace, in which prices will be set to their highest point. The desired marketplace is one with stable prices that are competitive.

3.3 InfoCenters Behaviors

We have currently implemented InfoCenter agents with four capabilities that give them advantages over classical sellers. First, InfoCenters can offer new information products after having approached an InfoSP, who manipulates a given piece of information. Second, InfoCenters may switch among the commodities they offer for sale. Since InfoCenters do not "hold in stock" the information they sell, these agents can flexibly decide upon the area in which to specialize. Third, we have implemented a mechanism for sharing information among InfoCenters, so that information remains distributed and its price is not necessarily handled by a monopolistic agent. Fourth, we implemented capabilities that enable the InfoCenters to act more intelligently. These include: 1) using planning in order to choose wisely which InfoSPs' services to use, 2) using communication protocols when approaching buyers in order to understand their needs, and 3) using decision-making algorithms for choosing what information to offer.

3.3.1 Manipulated Information

InfoCenters can approach InfoSP agents so as to provide buyers and sellers with new information products. The information manipulation methods that the InfoSP can offer include:

- Different presentation formats and resolutions — Resolution may depend on the connection speed available to the consumer. The buyer may wish to match the format of the information to the device he is using (e.g., the device can be a PC, a handheld, a cellular phone, a fax-machine, or a printer). Currently, we have implemented a unary operator that, for example, enables the presentation of information to be either in PS or PDF formats.

- Information updates — The InfoSP can offer updates to existing pieces of information. This is relevant when the information in question may change over time, for example, information that refers to cost rates, stock values, news, and reviews. This operator was left for future implementation.

- Combining and summarization — The information requested by a consumer may require the combination of several information pieces. In addition, the resulting information may consist of non-relevant information that should be removed. Currently, we have implemented a binary operator called *collector* that enables the combination of two pieces of information into a single unit.

For simplicity, the price paid by InfoCenters to InfoSPs for services provided was fixed, and did not change according to marketplace demands.[1]

We assume that the time needed by the InfoSP to apply any of the operators is very small. Therefore, InfoCenters can offer information that was manipulated by various InfoSPs. If buyers are interested in some new information that is not offered by any seller, then the InfoCenter will contact relevant InfoSPs and will produce the information. Only then will the InfoCenter pay the InfoSPs. In that way, InfoCenters and InfoSPs can check the demand for different information commodities.

The InfoCenter agent can respond to a market request for an information commodity, and plan a way to make it available, using the information sources and the InfoSP services that are available. It can replace information commodities with more profitable ones. The InfoCenter's ability to introduce new information commodities using the InfoSP should be used 'wisely'. Unwise use of InfoSP services can lead to lower profits. For example:

1. An InfoCenter that intends to produce a collection of translated information can do it in several ways. One way is to approach an InfoSP to translate each piece of information and then to collect them using another InfoSP. Or, it can collect them first and then translate the collection. The second approach is preferred since it uses the translation services only once instead of translating each piece of information separately.

2. Offering new information may reduce the profit of the InfoCenter that offers it. For example, given a market in which one InfoCenter sells information A, another InfoCenter sells information B, and buyers want

[1]We plan on adapting the cost of manipulated information to market demands, since this cost is affected by the prices of information commodities of which it consists, and these prices change according to market demand.

both pieces, A and B. One InfoCenter can buy the other piece of information from the other InfoCenter, and offer the combined information. Buyers will prefer the combined information, which will lead the other InfoCenter to offer it too. But then, both InfoCenters will be competing over the price of the new product and therefore, they will no longer be the only agents that offer this new information. Hence, the average price and the profit will decrease.

3.3.2 Switching between Information Commodities

InfoCenters can choose which information commodities they sell. An InfoCenter can stop offering a commodity he used to sell, and decide instead to sell another commodity for which there is a seller in the market. This action of switching information and contracting the sellers that offer that information will cost a certain fee. This fee is paid to the new sellers so they will hold a certain stock of information for the InfoCenter.

There is a trade-off between choosing which commodities to offer, and the profit from selling them. The following algorithms were tested to study this trade-off.

- MI (Moment Impulse) — an InfoCenter will switch between commodities and will pay a fee if the new commodity is more profitable than the commodities that are currently offered. The agent does not consider the past history of sales nor of demand.

- HM (History Measure) — an InfoCenter will switch between commodities and will pay a fee if the new commodity is more profitable when taking into account past prices. It will give more weight to prices in the recent past and present, than to prices in the distant past, but it doesn't consider the demand for those commodities.

- MA (Market Analyze) — an InfoCenter will switch between commodities and will pay a fee if the new commodity is more profitable when considering the past and the demand for it. The current profit will be computed with a time discount factor. The weight given to profit is proportional to the time that has passed.

3.3.3 Cooperative InfoCenters

InfoCenters can share resources. That means that an InfoCenter I_1 can approach another InfoCenter I_2 in order to sell information products that are not accessible to I_1. In such cases, InfoCenters are not competing, but are rather helping one another to sell their products. Moreover, an InfoCenter doesn't need to have information in all areas, but can specialize in a certain niche and use other InfoCenters when other information is needed.

We implemented a SharedCatalog model to enable such cooperation among InfoCenters. The SharedCatalog enables InfoCenters to share their commodities. When one InfoCenter wants to offer a commodity that it doesn't have, it can offer it to a buyer using the SharedCatalog. Then, assuming the commodity's price is P, and the buyer pays the InfoCenter a higher price P', the profit to the InfoCenter will be given by $P' - P$. Buyers who approach an InfoCenter with a request for information will get the product with the lowest price offered. Even if there are several InfoCenters that offer the same commodity with different prices, buyers obtain, from the InfoCenter that they have approached, the offer with the lowest price (this process is transparent to the buyers). If there are several InfoCenters that offer the same commodity with the same lowest price, then one InfoCenter will be chosen randomly.

3.3.4 InfoCenters that use AI techniques

InfoCenters can use AI techniques. These techniques can enable the InfoCenters to better understand market conditions, and in that way to increase their profit. The techniques include planning, decision making, and cooperation. In this section, we will explain how some of those AI techniques can help InfoCenters.

InfoCenters can approach buyers in order to understand the buyers' needs. Then InfoCenters can use this data in order to decide what information they want to offer. There are different protocols that InfoCenters and buyers can use in order to communicate. For example, the FIPA [FIP] and OMG [OMG] organizations offer communication languages, protocols, and infrustructures. In our simulation, we assumed that InfoCenters and buyers are using one of the available standards for communication. We focused on the algorithms that the inteligent agents will have to use, when they want to decide what information they want to offer.

The InfoCenter can use the InfoSPs' services in order to manipulate information. We presented in Section 3.3.1 two cases when unwise use of the InfoSPs' services can reduce the profit of the InfoCenters. Therefore, the intelligent InfoCenter can be assisted by planning techniques in order to choose the best services (i.e., operators) offered by the InfoSPs.

InfoCenters can cooperate in order to help one another, and in that way to help themselves be more profitable. In Section 3.3.3, the InfoCenter assisted the sellers to specialize in a niche, and in that way they toned down the price war and therefore increased the profit.

When InfoCenters operate as autonomous agents, then the need for cooperation by choosing a niche is not needed. This is because sellers have intial information that they want to sell. Therefore, InfoCenters can help sellers to choose what information to sell and what not to sell, and in that way to increase the profit. But when InfoCenters operate as autonomous agents then they will specialize in a niche, assuming that they will wisely choose what information to offer. We dealt with wise information choice in the previous points, mainly using information about buyers' requests, and wisely using InfoSPs' services.

Cooperation can be used for additional purposes, including information sharing of InfoSPs' services and information sharing of buyers' requests. We leave those subjects for future research.

Chapter 4

Simulation, Results and Analyze

4.1 Simulation Settings

In this Section, we present the simulations performed to test the impact of adding InfoCenter agents and Information Service Providers to an e-market. One simulation consists of a series of repeated encounters between finite sets of buyers, sellers, and InfoCenters. A finite set of basic commodities is offered for sale by the sellers. New commodities can be created by InfoSPs and can be sold by InfoCenters.

Sellers and InfoCenters offer the information products that can be bought. Each product is initialized with a fixed price. Each seller holds an infinite amount of the products offered. The cost of producing a basic commodity was set to 0.[1] During one simulation, the price is updated according to the sellers' strategies at a given rate ρ_s. The buyers choose a seller, based on the products they are interested in and based on their strategy (as explained below).[2] The buyers approach the sellers at a rate ρ_b. Once a buyer approaches a seller, the transaction is necessarily performed between the two.

The utility of a seller S at time t, after he has sold r products at a price P, is given by $U(S,t) = (\Sigma_{i=1}^{r} P(t))/r$. The utility of a buyer B at time t, after he has bought r products at a price P is $U(B,t) = v - (\Sigma_{i=1}^{r} P(t))/r$.[3] The

[1]A commodity created after applying an operator by the InfoSP incurs an additional cost.

[2]There is a central agent that responds to each buyer's request with a list of all the sellers that sell the requested items. Each buyer applies the corresponding algorithm to choose which seller to approach from this list.

[3]v denotes the value of one commodity for the buyer. In our implementation we assume all basic commodities have the same value: 1. The new information has a value depending

utility of an InfoCenter I at time t is given by $U(I,t) = (\Sigma_{i=1}^{r} P(t) - C_{f_j}(t))/r$, where $C_{f_j}(t)$ expresses the costs incurred by the InfoCenter from following each one of its behaviors given by its features. For example, C_{f_1} is the cost of approaching an InfoSP. C_{f_2} is the cost incurred from paying a seller for its information product.

Kephart et al. [KHG00] implemented a market with buyers and sellers solely. The sellers have different pricing algorithms. The authors tested the dynamics of the prices and the dynamics of the agents' behaviors in the given market. Here, we show the added value of implementing InfoCenter agents in the market, by enriching the information products that can be offered to buyers.

4.1.1 Buyers' and Sellers' Strategies

Buyers need to choose from which seller they will buy the commodity of interest. We have examined three algorithms that were implemented by information consumers (these same algorithms were implemented by Kephart et al. [KHG00]). The numbers in parentheses represent the percentage of such buyers in our tested market:

1. Compare-All (70%) — Buyers compare all of the prices requested for the commodity of interest. Then, buyers will choose the seller that asks for the lowest price. This algorithm is similar to the implementation of the ShopBot in [KHG00].

2. Compare-None (10%) — Each buyer chooses, randomly, an information source that offers the requested commodity.

3. Compare-two (20%) — Each buyer chooses two information sources randomly and then buys from the cheaper one.

The information suppliers in the marketplace apply three algorithms for changing the price of their commodity (following Kephart et al.'s model [KHG00, KG99]):

1. GT (Game Theory) — Kephart et al. have shown that there is not a single pure strategy that is in Nash equilibrium for sellers to establish the price of a commodity. There is, instead, a mixed strategy that is in Nash equilibrium. This mixed strategy instructs each seller to choose prices randomly using the following function $p(F)$, where F is a random

on what it contains (e.g., combined information of two basic information pieces will have a value of 2).

value between the cost c of the commodity and its value v (in our case $F \in [0,1]$). S denotes the number of sellers in the market, and w_i is the fraction of buyers that compare i prices. $p(F) = c + \frac{w_1 * (v-c)}{\Sigma_{i=1}^{S} i * w_i * (1-F)^{i-1}}$.

2. MY (Myoptimal) — The seller sets the price of the commodity in the market to maximize its short-term profit (i.e., it assumes that current known market conditions do not change, which is true in the short-term). This method requires knowledge about the buyer population W, the number of competing sellers S, and all of the sellers' prices.

3. DF (Deviate Follower) — The seller keeps increasing the price of a commodity as long as its profit increases. The seller will decrease the price when the profit drops off a certain level. The seller will continue decreasing the price as long as its profit increases, and so forth.

4.2 Experiments

In this Section, we report on the simulations performed to test the impact of adding InfoCenter agents and Information Service Providers to an E-market. As a preliminary step, we have implemented a market in which InfoCenter agents are attached to the information suppliers. That is, the InfoCenter agents do not pay any payment to the sellers (the InfoCenter and the sellers can be regarded as a single agent). In other words, the system we have implemented can be understood as a Full Price system in which the buyers necessarily approach the InfoCenters and cannot approach the sellers directly. We have motivated an FP system as one that includes InfoCenters that sell manipulated information. We have also tested all of the InfoCenter behaviors in such a case, i.e., even when the InfoCenter does not sell manipulated information but can cooperate with other InfoCenters.

The next step was to observe the impact of the InfoCenters when they operate as autonomous agents. We explored the effect of the different pricing algorithms and the different payment's methods. We wrap up by exploring the effects that the AI techniques have on the InfoCenters in a marketplace with a selective buyers. The experiments settings are described below.

4.2.1 InfoCenters Operate as Sellers' Assistants

In the simulations described below, we examined whether the addition of InfoCenter agents to E-markets is beneficial, i.e., whether they gain a positive profit. Since our results support this, we have also tested the impact the InfoCenters have on the market after implementing their possible behaviors as described in Section 3.2. In all of the markets studied, there were two basic commodities, five InfoCenters, and one hundred buyers. In order to analyze these resulting markets we distinguish between two main scenarios:

1. Homogeneous InfoCenter Agents — In this case, all of the InfoCenter agents were run with the same capabilities. We tested four different sub-cases:

    (a) Basic — When each InfoCenter offers its own commodities, the InfoCenter does not use the SharedCatalog, and the InfoCenter cannot switch among commodities.[4].

    (b) Cooperative — When the InfoCenters use the SharedCatalog, but cannot switch among commodities.

[4]This case is similar to the one implemented in Kephart et al. [KHG00]

(c) Switching — When the InfoCenters use the SharedCatalog, and also have the capability to switch among commodities (based on the MI, HM, and MA strategies described in Section 3.2. MI will cause the sellers to switch more often between commodities, and MA will induce the slowest rate of switching).

(d) Manipulated Information — When the InfoCenters approach the InfoSPs' services in order to offer new information commodities.

2. Heterogeneous InfoCenter Agents — In this case, we simulated markets with two sets of InfoCenters, where each set applied one of the aforementioned capabilities.

4.2.2 InfoCenters Operate as Autonomous Agents

In the simulations described below, we examined whether the addition of InfoCenter agents to e-markets is beneficial, i.e., they gain a positive profit. In all of the markets studied, there were two basic commodities, three sellers, and one hundred buyers. The number of InfoCenters in each scenario varies as described below:

1. No InfoCenters — In this case, there will be only sellers implementing the same pricing algorithm. We will use this as a control group so we can evaluate the effect of the existence of InfoCenters in the marketplace.

2. A Single InfoCenter Agent — In this case, there is one InfoCenter that interacts with several information suppliers and with InfoSPs in order to obtain manipulated information.

3. Homogeneous InfoCenter Agents — In this case, there are three InfoCenters that implement the same pricing and payment algorithms.

4. Heterogeneous InfoCenter Agents — In this case, we have simulated markets with two sets of InfoCenters, where each set followed different pricing and payment algorithms.

Furthermore, we check the effects that the different discount methods (as stated in Section 3.2) have. All of the following discount methods were tested in all of the marketplace configurations with one InfoCenter and with homogeneous and heterogeneous sets of InfoCenters:

1. Discount price of 10%

2. Discount price of 20%
3. Discount price of 50%
4. Average price
5. Minimum price

Moreover, we have tested the influence of the ratio between the subscription payment and the royalty payments as described in Section 3.2. We tested all of the following ratios in all of the marketplace configurations with one InfoCenter, and with homogeneous and heterogeneous sets of InfoCenters.

1. 80% of the price will be paid in the subscription payment and the remaining 20% will include royalty payments.
2. 50% of the price will be paid in the subscription payment and the remaining 50% will include royalty payments.
3. 20% of the price will be paid in the subscription payment and the remaining 80% will include royalty payments.

4.2.3 InfoCenters use AI Techniques

In this section we would like to explore the advantages that the InfoCenters can have when using AI techniques. Therefore, we compare the profit of InfoCenters that use inteligent techniques and InfoCenters that do not use those techniques. Both "dumb" and "inteligent" InfoCenters are capable of approaching InfoSPs in order to manipulate information. In this section, we investigate the following intelligent techniques that an InfoCenter can use.

The first technique is to use decision-making algorithms in order to decide what information to offer. The InfoCenter can approach buyers in order to understand what information they are interested in. Then the InfoCenter can use this data in order to choose the information it wants to offer.

The second technique is to use planning in order to choose wisely the InfoSPs' services. The InfoSPs' services are operators that can operate on pieces of information and create new information. The same infomation can be created using different operators. Therefore, the InfoCenters can use planning[5] in order to decide which InfoSPs' services it wants to use and in what order.

[5]In this experiment we used a naive planning algorithm, which explored all the possible plans and chooses the best one. We were able to do it because there were small number of information products and InfoSPs. In more complex markets the InfoCenters will have to use better planning techniques. We leave this for future work.

In order to investigate the effectivness of those techniques, we implemented the following marketplace. There are two types of basic information, one hundred buyers, and two types of InfoSPs' services: translation and combine. The buyers are interested only in specific information, which is the bundle of the basic information and its translation. For that information they are willing to pay up to 5 units. For the basic information, as in the previous experiment, the buyers are willing to pay up to 1 unit. For other information, which they are less interested in, they are willing to pay up to 0.5 unit.

In order to analyze these resulting markets, we distinguish between three main scenarios:

1. A Single InfoCenter Agent — In this case, there is one InfoCenter that interacts with several information suppliers and with InfoSPs in order to obtain manipulated information. The InfoCenter can use one of the following capabilities:

   (a) InfoCenters that do NOt use AI techniques (NOAI) — We will use this as a control group so we can evaluate the effect of applying AI techniques.

   (b) InfoCenters that use PLANning techniques (PLAN) — In this case, we enable the InfoCenters to use planning techniques in order to choose which InfoSPs' services they want to use.

   (c) InfoCenters that can APPRproach buyers (APPR) — In this case, we enable the InfoCenters to approach buyers in order to understand their needs, and then to use this data when deciding what information to offer.

   (d) InfoCenters that use PLanning and that can APproach buyers (PLAP) — In this case, the InfoCenters have the previous two capabilities. That is, the InfoCenters can approach buyers in order to understand what information they need, and then to use this data when deciding what information to create. Then, the InfoCenters can use planning techniques in order to choose the best InfoSPs' services in order to create that information.

2. Homogeneous InfoCenter Agents — In this case, there are three InfoCenters that implement the same aforementioned capabilities.

3. Heterogeneous InfoCenter Agents — In this case, we have simulated markets with two sets of InfoCenters, where each set followed the aforementioned capabilities.

Configuration	MY	GT	DF
Basic	0.45	0.09	0.52
Cooperative	0.62	0.38	0.50
Switching (MI)	0.84	0.76	0.45
Switching (HM)	0.77	0.73	0.57
Switching (MA)	0.84	0.73	0.62
Manipulated Information	0.78	0.40	0.56

Table 4.1: The InfoCenters' profit in the homogeneous market

4.3 Results

4.3.1 InfoCenters Operate as Sellers' Assistants

We expected to obtain two results for all of the settings tested. First, the InfoCenters will specialize in niches of information when InfoCenters cooperate, and each one will become a monopolist. However, our simulations show that there is continuous competition among the InfoCenters. InfoCenters are tempted to reduce prices below the monopolist price for a short time, in order to compete with the monopolists and to gain more buyers. Second, the InfoCenters were expected to increase their profit due to the introduction of new information commodities. In the simulations it was shown that unless the InfoCenters cooperate and do not sell the same new commodities all together, they will enter into a price war in which the competition will lead to a reduction in the profit from newer commodities.

We report on our results based on the settings described in Section 4.2.

Homogeneous InfoCenter Agents

In the short term, InfoCenters that trade manipulated information become monopolists over products that are not yet offered by other InfoCenters. Their average profit is larger than Cooperative and Switching InfoCenters. But, in the long term, when all InfoCenters become sellers of the same new products, their average profit decreases, and the Switching InfoCenters' utility gets larger. Switching InfoCenters are the most advantageous due to the periods of time when they can sell at the monopolist price. The Cooperative case (without switching) can be more beneficial than the basic one, if the commodities are distributed among the InfoCenters in a way that the InfoCenters become monopolists. Otherwise, the average gain obtained by Cooperative InfoCenters is equal to the Basic case. The profits of InfoCenters in this configuration are described in Table 4.1.

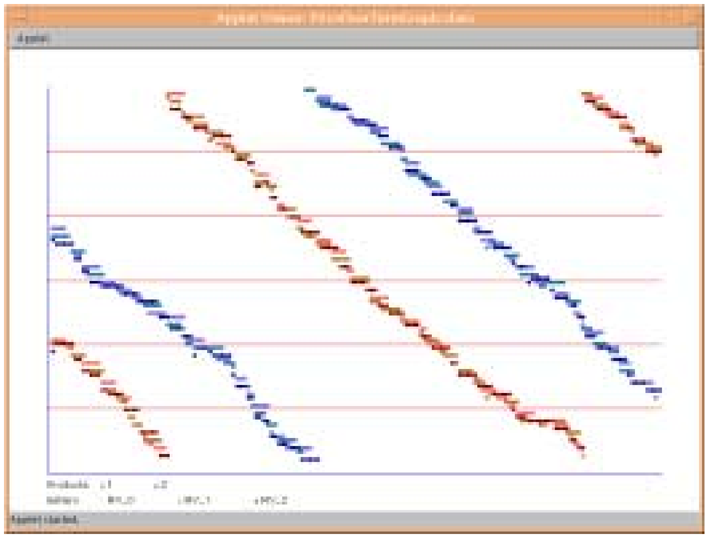

Figure 4.1: InfoCenter that use the MY pricing algorithm in a marketplace in the basic case. The price war over the two information products reduce the prices to their marginal cost, and then set the prices back to the maximum value (i.e., v).

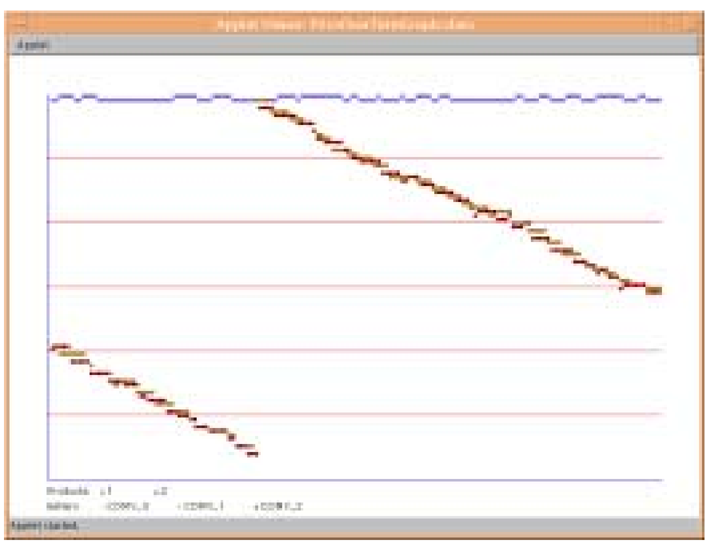

Figure 4.2: InfoCenter that use the MY pricing algorithm in a marketplace when InfoCenters cooperate. One information product is offer in the monopolist price by one InfoCenter, and the second information product has a lowest price change because it is offered by only two InfoCenters.

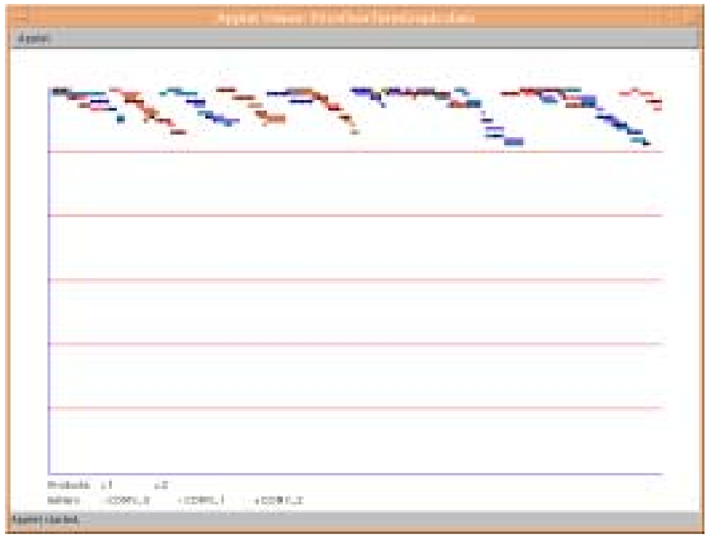

Figure 4.3: InfoCenter that use the MY pricing algorithm in a marketplace when InfoCenters cooperate and can switch the information product that they are offering. Since the InfoCenters can switch the information that they offer, then the price of the infromation products does not reduce under a certain level.

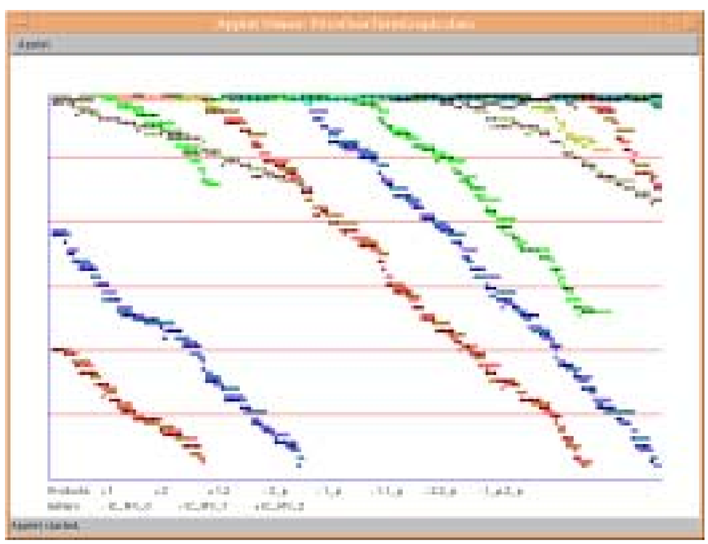

Figure 4.4: InfoCenter that use the MY pricing algorithm in a marketplace when the InfoCenter can approach an InfoSP in order to manipulate information. We can see the two basic information products as well as the new information products that were created by the InfoCenters using the InfoSPs services.

In the Basic case, as can be seen in Figure 4.1, a cyclic price war was detected (as was also shown by Kephart et al.). The price of each commodity changes between its lowest and highest possible price.

In the Cooperative case, as can be seen in Figure 4.2, there are fewer sellers that offer the same commodity (because InfoCenters cooperate and can sell the commodities of other sellers). Therefore, the price changes at a slower rate than in the case where there is only one seller that offers a commodity and sets its price according to the monopolist price.

In the Switching case, as can be seen in Figure 4.3, the InfoCenters switch to more profitable commodities. An InfoCenter will move away from a commodity offered by many InfoCenters at a low price to a commodity that can be sold at a higher price (i.e., because fewer InfoCenters offer it).

In the Manipulated information case, as can be seen in Figure 4.4, InfoCenters can offer new information commodities using the InfoSPs' services. The average profit depends on several parameters: the service cost, the number of commodities that an InfoCenter can offer, and the value that the information has for buyers (the v parameter). The cost of InfoSP services determines the profitability of the new information commodity. Higher service costs will cause lower profits for the InfoCenter. It is reasonable to limit the number of information elements that one InfoCenter can offer, because the number of all possible commodities that can be created is exponential in the number of basic commodities in the market. If there is no limitation imposed on the number of newly created commodities, then the Manipulated Information case yields results similar to the Basic case. If the number of new information products is indeed limited, then market behavior will be similar to the switching case market, when InfoCenters switch among commodities to gain higher profit.

Comparing our results to those obtained in Kephart et al. in [KHG00], the InfoCenter model leads to a higher average profit for the InfoCenter agents. This happens due to the existence of a monopolist agent. At the individual level, the non-monopolist agents obtain the same profit as in Kephart et al.'s model. InfoCenter agents that were also allowed to switch among commodities obtain a larger profit on average as well as at the individual level. The possibility of changing the commodities offered to information consumers led to higher prices in the market. Manipulated information was not handled by Kephart. Not only was this case shown to behave similarly to the Switching market when the amount of newly produced information is limited, and therefore the InfoCenters' average profit is the highest, but buyers also benefit from being able to acquire newer information products.

1 IC 4 IC	Basic	Cooperate	Switching	Manipulated Information
Basic	0.44 0.44	0.38 0.45	0.40 0.44	0.94 0.43
Cooperate	0.86 0.53	0.51 0.51	0.61 0.47	0.87 0.40
Switching	0.84 0.74	0.80 0.75	0.78 0.78	0.93 0.77
Manipulated Information	0.41 0.78	0.42 0.76	0.79 0.76	0.79 0.79

Table 4.2: The InfoCenters' profit in the heterogeneous market, when the InfoCenters use the MY algorithm and the switching is done using the MI algorithm.

In our model, prices change at a rate that is slower than in [KHG00].[6] On the one hand, buyers can benefit from this fact, since they will be able to buy at the same price for a longer period. On the other hand, when InfoCenters switch among commodities, the price changes more slowly but does not arrive at the minimal price as in the model presented in [KHG00], because the InfoCenters benefit more from switching to a more expensive commodity rather than from decreasing the price of the current commodity being offered.

Heterogeneous InfoCenter Agents

We have tested markets in which one InfoCenter follows any one of the Basic, Cooperative, Switching, or Manipulated Information behaviors and the other four InfoCenters follow a different behavior. We use the following notation to distinguish between these cases: $1X4Y$ where X and Y can be B for the Basic case, C for the cooperative case, S for the switching case, and M for the manipulated information case. When we explain a general result we will use the symbol $|$ to denote or, for example, a market with one InfoCenter that obtains manipulated information while the other four can follow any other behavior will be denoted as $1M4B|C|S|$. The results of the simulation are presented in Tables 4.2, 4.3 and 4.4. The profit of the single InfoCenter is placed in the top right corner of each cell, while the profit of the four other InfoCenters is placed in the bottom left corner.

[6] In the Manipulated case, the rate of price change decreases as long as fewer InfoCenters sell new products.

1 IC 4 IC	Basic	Cooperate	Switching	Manipulated Information
Basic	0.07 0.08	0.10 0.07	0.19 0.10	0.08 0.43
Cooperate	0.07 0.08	0.10 0.08	0.07 0.19	0.08 0.38
Switching	0.14 0.53	0.12 0.51	0.12 0.18	0.14 0.50
Manipulated Information	0.57 0.08	0.57 0.07	0.50 0.25	0.52 0.38

Table 4.3: The InfoCenters' profit in the heterogeneous market, when the InfoCenters use the GT algorithm and the switching is done using the MI algorithm.

1 IC 4 IC	Basic	Cooperate	Switching	Manipulated Information
Basic	0.44 0.55	0.53 0.31	0.49 0.42	0.45 0.55
Cooperate	0.68 0.49	0.53 0.35	0.50 0.58	0.69 0.48
Switching	0.11 0.49	0.18 0.49	0.46 0.56	0.06 0.46
Manipulated Information	0.85 0.50	0.85 0.37	0.51 0.19	0.55 0.45

Table 4.4: The InfoCenters' profit in the heterogeneous market, when the InfoCenters use the DF algorithm and the switching is done using the MA algorithm.

In the $1M4B|C|S$ case, the average profit of all the InfoCenters increases, in particular (and due to) the profit of the single Manipulated Information InfoCenter. This agent is the only one that can offer new information products and therefore it does not compete with any other seller in the market. In $4M1B|C|S$, the four InfoCenter agents compete with one another, leading the market to a similar basic homogeneous market with at least four Manipulated Information InfoCenters and a larger set of information commodities including the newly created. The average profit of the Manipulated Information InfoCenters will be lower than the average profit gained by the InfoCenters in the basic case, since the average cost of the commodities is higher.

The cases in which there is a single Cooperative or Switching InfoCenter are not relevant since this InfoCenter will not be able to cooperate. In a $1C4S$ market, the behaviors of the InfoCenters are similar to a homogeneous market with five Switching InfoCenters. When the four InfoCenters switch to more profitable commodities, the commodities' prices remain at higher prices. Then, the Cooperative InfoCenter takes advantage of this high price. In a $1S4C$ market, the result is similar to the case of five Cooperative InfoCenters. Although the Switching InfoCenter has the capability of switching between commodities, the four Cooperative InfoCenters will nevertheless enter a price war that will cause a reduction in the prices of the commodities.

A Basic InfoCenter in any heterogeneous market is never more profitable than a non-Basic InfoCenter. The capabilities added in all the non-Basic behaviors always increase the profit of the InfoCenters that follow them. Notice that this conclusion justifies the implementation of InfoCenters in E-markets.

Moreover, from all the simulations run, we can also advise the design of an InfoCenter with both Switching and Manipulate Information capabilities. We expect that these will result in the most profitable InfoCenters.

Trading with manipulated information enriches the market with newer information products and therefore improves the situation of InfoCenters as compared to regular sellers. Additionally, the buyers in this E-market benefit from being able to request richer and newer information products. If there are other InfoCenters implemented in the same E-market, we learned from our simulations in heterogeneous settings that a single Manipulated Information InfoCenter benefits the most, since it offers products that the others do not have, and can sell them at a monopolistic price.

Switching among commodities increases profit over Basic InfoCenters. Therefore, we expect that Switching will contribute to the Manipulated Information InfoCenters increasing their average profit as well, by avoiding entering price wars over products. If there are other InfoCenters in the

E-market that are Manipulated Information as well, the Switching characteristic will enable the InfoCenters to specialize in niches and will be less influenced by price wars by switching to more profitable commodities.

4.3.2 InfoCenters Operate as Autonomous Agents

Seller and InfoCenter Behavior

We consider a marketplace as a game, where each player represents a group of sellers or InfoCenters. We assume that all of the sellers are homogeneous in all the marketplace configurations, and therefore they will all choose the same pricing algorithm (i.e., MY, GT or DF) and will be represented by a single player. The InfoCenters will be represented by players depending on the market configuration: 1) the single InfoCenter will be represented by a single player, 2) the homogeneous InfoCenters, like the homogeneous sellers, will be represented by a single player, and 3) the heterogeneous marketplace includes two groups of InfoCenters, the single InfoCenter that will be represented by one player, and the other homogeneous four InfoCenters that will be represented by an additional player. Each player chooses a pricing strategy (i.e., MY, GT or DF) and a payment method (i.e., FP, WP or SP) in case it represents an InfoCenter. The profit of each player in the game is the average profit of the agents it represents.

We would like to find out if there is an equilibrium for this game in each market configuration. If there is such an equilibrium, we call it the strategic equilibrium of the marketplace. From now on we will refer to an InfoCenter that applies the pricing algorithm MY and the payment method WP as an InfoCenter that uses MY with WP.

The sellers' profit is higher when they implemented the DF pricing algorithm over the MY and GT pricing algorithms in all market configurations (as will be shown later in Table 4.14).

In the marketplace with a single InfoCenter (see Table 4.5), the InfoCenter benefits more from implementing the full price (FP) payment method no matter what pricing method the sellers have implemented. As seen in this table, the single InfoCenter will benefit most by applying the GT pricing algorithm when sellers implement the DF algorithm. The same result is obtained when sellers apply the MY algorithm. However, the single InfoCenter will prefer the MY pricing algorithm when sellers follow the GT algorithm. Since sellers prefer to use the DF pricing algorithm as mentioned before, the InfoCenter will then prefer to use GT with FP, and this is the market strategic equilibrium. The InfoCenter will obtain an average profit of 1.45 and the seller will obtain an average profit of 0.5, as can be seen in Table 4.5.

IC Algorithm	IC payment	Seller Algorithm	IC Profit	Sellers' Profit
DF	FP	DF	0.52	0.51
DF	SP	DF	0.32	0.49
DF	WP	DF	0.28	0.50
GT	FP	DF	1.45	0.50
GT	SP	DF	0.71	0.50
GT	WP	DF	0.75	0.47
MY	FP	DF	0.97	0.52
MY	SP	DF	0.64	0.53
MY	WP	DF	0.68	0.50
DF	FP	GT	0.67	0.08
DF	SP	GT	0.34	0.12
DF	WP	GT	0.48	0.08
GT	FP	GT	1.64	0.10
GT	SP	GT	1.09	0.12
GT	WP	GT	1.16	0.09
MY	FP	GT	1.69	0.09
MY	SP	GT	1.21	0.12
MY	WP	GT	1.22	0.08
DF	FP	MY	0.62	0.47
DF	SP	MY	0.40	0.50
DF	WP	MY	0.35	0.48
GT	FP	MY	1.43	0.45
GT	SP	MY	0.63	0.48
GT	WP	MY	0.75	0.46
MY	FP	MY	1.22	0.47
MY	SP	MY	0.68	0.48
MY	WP	MY	0.67	0.47

Table 4.5: The profits of the InfoCenter and the sellers in a marketplace with a single InfoCenter

IC Algorithm	IC payment	Sellers Algorithm	IC Profit	Sellers' Profit
DF	FP	DF	0.34	0.49
DF	SP	DF	0.22	0.51
DF	WP	DF	0.15	0.52
GT	FP	DF	0.69	0.46
GT	SP	DF	0.45	0.47
GT	WP	DF	0.35	0.50
MY	FP	DF	0.70	0.48
MY	SP	DF	0.57	0.51
MY	WP	DF	0.50	0.50
DF	FP	GT	0.56	0.09
DF	SP	GT	0.38	0.13
DF	WP	GT	0.39	0.09
GT	FP	GT	0.95	0.10
GT	SP	GT	0.69	0.13
GT	WP	GT	0.66	0.09
MY	FP	GT	0.97	0.08
MY	SP	GT	0.80	0.13
MY	WP	GT	0.75	0.08
DF	FP	MY	0.43	0.46
DF	SP	MY	0.32	0.50
DF	WP	MY	0.27	0.45
GT	FP	MY	0.59	0.40
GT	SP	MY	0.31	0.49
GT	WP	MY	0.37	0.40
MY	FP	MY	0.66	0.47
MY	SP	MY	0.47	0.50
MY	WP	MY	0.43	0.49

Table 4.6: The profits of InfoCenters and sellers in a marketplace with three homogeneous InfoCenters

In the homogeneous marketplace (see Table 4.6), the InfoCenters gained the highest profit using MY with FP, no matter what pricing method sellers have implemented. Sellers will prefer the DF pricing algorithm no matter what pricing and payment method the homogeneous InfoCenters have implemented. Therefore, the equilibrium found will be when InfoCenters use MY with FP and sellers use the DF algorithm. InfoCenters will obtain an average profit of 0.7 and sellers will obtain an average profit of 0.48, as can be seen in Table 4.6. The single InfoCenter (results shown in Table 4.5) obtained an average profit of 1.45 in the equilibrium case because then it was a monopolistic agent. In the homogeneous market, InfoCenters applied the same algorithm, but they also compete with one another.

The influence of the different payment methods in a marketplace with heterogeneous InfoCenters can be seen in Tables 4.7, 4.8 and 4.9. The single InfoCenter gains the highest profit when applying the FP payment method at about 74% of the configurations, and the four InfoCenters at about 44% of the tested configurations. We could not found any equilibrium in this marketplace configuration.

Different Sellers' Discounts

The InfoCenters do not behave as usual buyers because they buy more information than regular buyers. Therefore, sellers may benefit from giving them discounts. The seller can offer discounts with the Wholesale Price (WP) and with the Subscription Price (SP). In this section, we compare the different discount methods mentioned in Section 4.2.

Since in the previous section we showed that sellers gain the highest profit when using the DF pricing algorithm no matter what payment method or discount was used. Therefore, in this section we will present only the results when the sellers use the DF pricing algorithm.

We expected that sellers would gain the highest profits with the lowest discount, while the InfoCenters would gain the highest profit with the highest discount. But the simulation actually showed the opposite (see Table 4.10). The reason is that InfoCenters can benefit from higher prices, because then the prices they set are higher, too. Sellers benefit from higher discounts, because it enables them to offer attractive prices for InfoCenters, and in that way to sell more information and increase their profit. No preferred discount method was found. It depended on the seller and InfoCenter algorithms, as can be seen in Table 4.10.

The Subscription Payment (SP) consists of two parts: a subscription fee that is paid in order to become a subscriber, and royalty payments that are paid for each unit of information that was purchased. We will denote a mar-

Single InfoCenter Algorithm	Single InfoCenter Payment	Four InfoCenters Algorithm	Four InfoCenters Payment	Single InfoCenters Profit	Four InfoCenters Profit	Sellers Profit
DF	FP	DF	FP	0.27	0.34	0.51
DF	FP	DF	SP	0.01	0.23	0.51
DF	FP	DF	WP	0.32	0.13	0.46
DF	FP	GT	FP	0.45	0.54	0.51
DF	FP	GT	SP	0.55	0.45	0.47
DF	FP	GT	WP	0.30	0.63	0.50
DF	FP	MY	FP	0.30	0.99	0.53
DF	FP	MY	SP	0.41	0.48	0.48
DF	FP	MY	WP	0.35	0.74	0.50
DF	SP	DF	FP	0.32	0.09	0.50
DF	SP	DF	SP	0.30	0.23	0.51
DF	SP	DF	WP	0.25	0.18	0.50
DF	SP	GT	FP	0.28	0.64	0.51
DF	SP	GT	SP	0.32	0.60	0.47
DF	SP	GT	WP	0.28	0.62	0.49
DF	SP	MY	FP	0.29	0.78	0.50
DF	SP	MY	SP	0.29	0.88	0.46
DF	SP	MY	WP	0.19	0.45	0.52
DF	WP	DF	FP	0.36	0.03	0.46
DF	WP	DF	SP	0.30	0.16	0.48
DF	WP	DF	WP	0.16	0.19	0.50
DF	WP	GT	FP	0.20	0.57	0.49
DF	WP	GT	SP	0.25	0.46	0.51
DF	WP	GT	WP	0.23	0.41	0.52
DF	WP	MY	FP	0.34	1.05	0.48
DF	WP	MY	SP	0.35	0.73	0.51
DF	WP	MY	WP	0.30	0.63	0.46

Table 4.7: The profits of InfoCenters and sellers in a marketplace with five heterogeneous InfoCenters in a marketplace when all the sellers use the DF algorithm (when the single InfoCenter uses the DF algorithm)

Single InfoCenter Algorithm	Single InfoCenter Payment	Four InfoCenters Algorithm	Four InfoCenters Payment	Single InfoCenters Profit	Four InfoCenters Profit	Sellers Profit
GT	FP	DF	FP	0.69	0.34	0.52
GT	FP	DF	SP	0.87	0.24	0.55
GT	FP	DF	WP	0.52	0.25	0.51
GT	FP	GT	FP	0.68	0.84	0.47
GT	FP	GT	SP	0.50	0.03	0.49
GT	FP	GT	WP	0.56	0.49	0.49
GT	FP	MY	FP	0.60	1.03	0.47
GT	FP	MY	SP	0.61	0.37	0.52
GT	FP	MY	WP	0.49	0.69	0.46
GT	SP	DF	FP	0.51	0.38	0.46
GT	SP	DF	SP	0.56	0.23	0.52
GT	SP	DF	WP	0.54	0.37	0.47
GT	SP	GT	FP	0.42	0.59	0.49
GT	SP	GT	SP	0.48	0.54	0.50
GT	SP	GT	WP	0.43	0.38	0.48
GT	SP	MY	FP	0.40	1.03	0.47
GT	SP	MY	SP	0.65	0.65	0.50
GT	SP	MY	WP	0.70	0.47	0.54
GT	WP	DF	FP	0.49	0.24	0.49
GT	WP	DF	SP	0.31	0.34	0.50
GT	WP	DF	WP	0.44	0.30	0.48
GT	WP	GT	FP	0.62	0.62	0.49
GT	WP	GT	SP	0.51	0.32	0.51
GT	WP	GT	WP	0.45	0.41	0.54
GT	WP	MY	FP	0.49	0.39	0.46
GT	WP	MY	SP	0.41	0.71	0.51
GT	WP	MY	WP	0.65	0.46	0.48

Table 4.8: The profits of InfoCenters and sellers in a marketplace with five heterogeneous InfoCenters in a marketplace when all the sellers use the DF algorithm (when the single InfoCenter uses the GT algorithm)

Single InfoCenter Algorithm	Single InfoCenter Payment	Four InfoCenters Algorithm	Four InfoCenters Payment	Single InfoCenters Profit	Four InfoCenters Profit	Sellers Profit
MY	FP	DF	FP	1.14	0.36	0.48
MY	FP	DF	SP	0.88	0.22	0.52
MY	FP	DF	WP	0.80	0.25	0.54
MY	FP	GT	FP	0.54	0.69	0.49
MY	FP	GT	SP	0.73	0.64	0.49
MY	FP	GT	WP	1.01	0.62	0.50
MY	FP	MY	FP	0.83	0.68	0.50
MY	FP	MY	SP	0.76	0.48	0.54
MY	FP	MY	WP	0.80	0.39	0.46
MY	SP	DF	FP	0.66	0.28	0.52
MY	SP	DF	SP	0.58	0.22	0.53
MY	SP	DF	WP	0.58	0.26	0.49
MY	SP	GT	FP	0.76	0.57	0.47
MY	SP	GT	SP	0.43	0.57	0.49
MY	SP	GT	WP	0.79	0.40	0.50
MY	SP	MY	FP	0.64	0.60	0.51
MY	SP	MY	SP	0.45	0.48	0.51
MY	SP	MY	WP	0.59	0.70	0.47
MY	WP	DF	FP	0.65	0.08	0.53
MY	WP	DF	SP	0.69	0.30	0.46
MY	WP	DF	WP	0.71	0.20	0.48
MY	WP	GT	FP	0.78	0.64	0.43
MY	WP	GT	SP	0.66	0.14	0.49
MY	WP	GT	WP	0.65	0.12	0.49
MY	WP	MY	FP	0.35	0.85	0.49
MY	WP	MY	SP	0.69	0.52	0.48
MY	WP	MY	WP	0.72	0.35	0.48

Table 4.9: The profits of InfoCenters and sellers in a marketplace with five heterogeneous InfoCenters in a marketplace when all the sellers use the DF algorithm (when the single InfoCenter uses the MY algorithm)

Configuration	InfoCenter(s) Algorithm	Profit	Different discount methods 10%	20%	50%	Avg	Min
Single IC	DF	IC	0.32	0.25	0.24	0.27	0.27
		Seller	0.50	0.45	0.50	0.47	0.47
	GT	IC	0.71	0.69	0.81	0.80	0.69
		Seller	0.47	0.45	0.50	0.49	0.50
	MY	IC	0.79	0.71	0.78	0.68	0.68
		Sellers	0.47	0.49	0.47	0.49	0.49
Homogeneous	DF	IC	0.17	0.10	0.13	0.11	0.19
		Seller	0.34	0.38	0.37	0.38	0.34
	GT	IC	0.49	0.53	0.35	0.36	0.28
		Seller	0.46	0.44	0.50	0.37	0.48
	MY	ICs	0.69	0.58	0.56	0.66	0.67
		Sellers	0.49	0.48	0.51	0.45	0.50
Heterogeneous 1 IC,4 ICs	DF,DF	1 IC	0.17	0.24	0.21	0.21	0.18
		4 ICs	0.20	0.21	0.21	0.16	0.21
		Sellers	0.52	0.48	0.46	0.49	0.50
	DF,GT	1 IC	0.31	0.22	0.38	0.22	0.16
		4 ICs	0.63	0.45	0.51	0.62	0.62
		Sellers	0.48	0.47	0.47	0.50	0.53
	DF,MY	1 IC	0.26	0.25	0.21	0.25	0.34
		4 ICs	0.61	0.56	0.49	0.54	0.45
		Sellers	0.48	0.51	0.49	0.51	0.49
	GT,DF	1 IC	0.55	0.49	0.43	0.54	0.55
		4 ICs	0.39	0.27	0.34	0.30	0.34
		Sellers	0.48	0.53	0.48	0.52	0.49
	GT,GT	1 IC	0.58	0.63	0.59	0.44	0.40
		4 ICs	0.58	0.46	0.36	0.72	0.44
		Sellers	0.48	0.49	0.49	0.49	0.50
	GT,MY	1 IC	0.43	0.57	0.54	0.53	0.27
		4 ICs	0.66	0.64	0.55	0.42	0.45
		Sellers	0.44	0.52	0.49	0.51	0.50
	MY,DF	1 IC	0.68	0.72	0.60	0.68	0.52
		4 ICs	0.16	0.24	0.22	0.16	0.28
		Sellers	0.50	0.51	0.48	0.46	0.46
	MY,GT	1 IC	0.76	0.49	0.66	0.47	0.44
		4 ICs	0.39	0.26	0.51	0.47	0.31
		Sellers	0.52	0.51	0.52	0.47	0.52
	MY,MY	1 IC	0.59	0.75	0.63	0.61	0.65
		4 ICs	0.51	0.42	0.41	0.52	0.41
		Sellers	0.49	0.49	0.51	0.51	0.50

Table 4.10: The profits of InfoCenters and sellers when they use different discount methods in a marketplace where the sellers use the DF algorithm

InfoCenter Algorithm	Sellers Algorithm	Different subscription ratio					
		(20%,80%)		(50%,50%)		(80%,20%)	
		IC	Sellers	IC	Sellers	IC	Sellers
DF	DF	0.29	0.51	0.30	0.51	0.34	0.49
GT	DF	0.78	0.47	0.67	0.49	0.71	0.47
MY	DF	0.80	0.46	0.66	0.51	0.61	0.50

Table 4.11: The profits of InfoCenters and sellers when they use different discount methods in a marketplace with a single InfoCenter

InfoCenters Algorithm	Sellers Algorithm	Different subscription ratio					
		(20%,80%)		(50%,50%)		(80%,20%)	
		IC	Sellers	IC	Sellers	IC	Sellers
DF	DF	0.19	0.38	0.27	0.36	0.20	0.38
GT	DF	0.42	0.46	0.51	0.38	0.35	0.39
MY	DF	0.60	0.46	0.77	0.46	0.67	0.44

Table 4.12: The profits of InfoCenters and sellers when they use different discount methods in a marketplace with three homogenous InfoCenters

ketplace in which there exists a ratio of 80% subscription payments and 20% royalty payments as a ratio of (80%,20%).[7] In both the homogeneous and heterogeneous configurations, the highest profit was achieved with the ratio (50%,50%). The ratio that yielded the highest profit for the single InfoCenter scenario was (20%,80%). Further tests are needed to better understand these results.

General Discussion

One of the objectives of this work was to test whether the inclusion of InfoCenter agents in an information e-marketplace is beneficial to sellers that supply pieces of information in such a market. On the one hand, the sellers are willing to sell the information to the InfoCenters with a discount when the InfoCenters buy large amounts of information from them. In that case, InfoCenters guarantee that they will buy large amounts of information from these sellers, and therefore these sellers know that they will continue to sell for a certain period of time. This behavior will cause sellers to sell at higher prices. On the other hand, this kind of interaction (i.e., giving a discount) reduces the sellers' prices and therefore their average profit. The effect of

[7]This payment method is the most general because the WP payment and the FP payment methods can be represented by (100%,0%) and (0%,100%), respectively.

Single InfoCenters Algorithm	Four InfoCenters Algorithm	Sellers Algorithm	Different subscription ratio		
			(20%,80%)		
			1 IC	4 ICs	Sellers
DF	DF	DF	0.26	0.17	0.46
DF	GT	DF	0.29	0.54	0.50
DF	MY	DF	0.33	0.55	0.45
GT	DF	DF	0.55	0.33	0.52
GT	GT	DF	0.34	0.56	0.52
GT	MY	DF	0.56	0.45	0.50
MY	DF	DF	0.68	0.35	0.46
MY	GT	DF	0.71	0.55	0.47
MY	MY	DF	0.59	0.57	0.46
			(50%,50%)		
			1 IC	4 ICs	Sellers
DF	DF	DF	0.28	0.15	0.47
DF	GT	DF	0.26	0.46	0.49
DF	MY	DF	0.28	0.48	0.54
GT	DF	DF	0.65	0.20	0.54
GT	GT	DF	0.66	0.45	0.48
GT	MY	DF	0.68	0.57	0.51
MY	DF	DF	0.74	0.25	0.48
MY	GT	DF	0.61	0.32	0.47
MY	MY	DF	0.53	0.70	0.52
			(80%,20%)		
			1 IC	4 ICs	Sellers
DF	DF	DF	0.33	0.19	0.48
DF	GT	DF	0.31	0.42	0.50
DF	MY	DF	0.18	0.40	0.55
GT	DF	DF	0.51	0.22	0.51
GT	GT	DF	0.37	0.63	0.53
GT	MY	DF	0.47	0.06	0.51
MY	DF	DF	0.75	0.19	0.49
MY	GT	DF	0.77	0.42	0.47
MY	MY	DF	0.50	0.56	0.48

Table 4.13: The profits of InfoCenters and sellers when they use different subscription ratios in a marketplace when all the sellers use the DF algorithm

	Sellers' Algorithm		
Market configuration	DF	GT	MY
No InfoCenter	0.49	0.09	0.47
Single InfoCenter	0.50	0.10	0.47
Homogeneous InfoCenters	0.49	0.10	0.46
Heterogeneous InfoCenters	0.49	0.10	0.47

Table 4.14: The sellers' average profit in different market configurations

the InfoCenters on the sellers' profit can be seen in Table 4.14. The sellers' average profit remains similar in all of the cases tested, but they sold more information which increased the total profit.

We expected that sellers and InfoCenters will get the highest profit by implementing the myoptimal (MY) or the game-theory (GT) pricing algorithm. This was due to the following reason: both the MY and the GT algorithms use information on buyers' demand and information about the prices set by other sellers. The MY algorithm sets the price optimally. In the case of GT, the price is set to one of the prices of the mixed equilibrium.

The Deviate-Follower (DF) pricing algorithm, on the contrary, does not have any information on buyers and sellers. Our results show that the InfoCenters indeed gain the highest profit when implementing the MY and GT algorithms. However, *sellers* gain the highest profit when implementing the DF algorithm. The DF algorithm reacts to market conditions and does not assume any behavior of buyers and sellers in the marketplace. This is in contrast to MY and GT, that try to set the best price according to market demand. The seller does not consider the InfoCenter when it decides on the price. This gives an advantage to the DF algorithm over the MY and the GT algorithms, because it regards the InfoCenter as part of general market conditions. Sellers are interested in setting prices for basic information products (i.e., they do not have to handle new products' prices as InfoCenters do). Therefore, they prefer the DF pricing algorithm which adapts better to market conditions.

Regarding the different discount methods, we expected that InfoCenters will benefit most from the discounts offered to them by the sellers. Our results do not support this conjecture. There are two cases in which discount payments are implemented: one is the Wholesale Price (WP), and the other is the Subscription Price (SP). When applying those payments, the InfoCenter guarantees to buy from one seller only. But, over time, there may be other sellers that will offer the information at lower prices. That is the reason that the InfoCenter does not necessarily benefit from those discounts.

	Sellers Algorithm		
Market configuration	DF	GT	MY
No AI	0.24	0.15	-0.10
Planning	0.81	1.14	0.08
Approacing buyers	0.53	4.23	4.24
Planning + Approaching Buyers	0.89	4.38	4.36

Table 4.15: The single InfoCenter average profit when using different AI techniques

When we evaluate market stability, we need to look at two distinct sets of information: the information that sellers sell and the new information that InfoCenters sell. This is because InfoCenters have no added value in re-selling the sellers information, while the sellers cannot offer the new information offered by the InfoCenters. The existence of the InfoCenters may increase the sellers' profit, but they will have to continue to be price competitive in order to sell information to InfoCenters and to regular buyers. Therefore, the behavior of the price of information that sellers offer will be similar to the case of a marketplace without InfoCenters. InfoCenters that offer new information behave like sellers in a marketplace with that information. In that way, the behavior of prices of new information is similar to the behavior of prices in a marketplace that does not contain sellers that offer the new information. In summary, we can say that the influence that the InfoCenters have on the marketplace is by adding new information to the market, but the InfoCenters do not change the price behavior of the information (that is, they do not increase the price of information and do not decrease the price of it).

4.3.3 InfoCenters use AI techniques

Single InfoCenter

In this section, we used a market configuration that makes the life of the InfoCenters and every other agent that wants to offer new information very hard. This is because the buyers are only interested in two specific pieces of information out of all the different information that can be offered. Though buyers are willing to pay well for the information they are interested in (i.e., 5 units), they will pay poorly for information that they are not interested in (i.e., 1 unit for basic information, and 0.5 unit for other information). This will cause the process of introducing new information to the market to be a hard and costly one. The InfoCenter will gain small profits and even lose money while looking for the information requested by buyers.

As we can see in Table 4.15, the profit of the InfoCenter in the market when it uses no AI technique is small. The InfoCenter in this case randomly chooses what information to offer. If it offers the requested information earlier, then it will gain enough profit from that information such that it will cover the money it lost while selling information with low demand. On the other hand, if it will take too long to offer information that has a high demand, then it might lose too much money and will have to go out of business (e.g., the InfoCenter that used the MY pricing algorithm).

The InfoCenter can use planning in order to choose the best InfoSPs' services. We can see in Table 4.15 that planning will increase the InfoCenter's profit. When the InfoCenter use planning, it reduces the cost of producing new infromation by choosing wisely the InfoSPs' sevices. The InfoSPs' services are not the elements that have the most significant effect on InfoCenter's profit. The significant elements are the sellers' prices of the information products that the InfoCenter buys in order to create new information, and the prices of the information that the InfoCenter sells to buyers. Therefore, planning increases the InfoCenter's profit, but other AI techniques can assist it in order to increase the profit even more.

The next technique that we apply was to understand what information the buyers are interested in by approaching them, and then using this data in order to choose what information to offer. By offering information that the buyers are inteterested in, the buyers will be willing to pay more for this information. This is related to elements that have more influence on the profit, which is the prices at which InfoCenters can sell their information. In Table 4.15, we can see that in this market, knowing what information the buyers are interested in can increase the profit of the InfoCenters significantly.

Nevertheless, the profit achieved by approaching buyers can be increased by using planning in order to create the information. We saw before that knowing what information to offer is more important than knowing how to create the information wisely. But when knowing what information to offer, you can still increase the profit if you will create the information wisely. As we can see in Table 4.15, approaching buyers and creating the information they are interested in wisely, will gain the highest profit.

Furthermore, we can see that planning gave a similar increase in profit to no AI InfoCenter as it gave to InfoCenters that approach buyers. This is because planning enables the InfoCenter to use the InfoSPs' services more efficiently no matter what information the InfoCenter wants to create. Therefore, InfoCenters that apply planning in order to use the InfoSPs' services wisely, will gain higher profit than similar InfoCenters that do not apply planning.

When comparing the InfoCenters profit in the NOAI configuration in this marketplace to the profit of the InfoCenters in the previous marketplaces configuration (i.e., in section 4.3.2), we can see that their profit had decreased significantly. This is because in this marketplace configuration the buyers are willing to pay less for information that they are less interested at. Furhtermore, because the buyers are willing to pay more for the information they are interested at, then the InfoCenters' profit in the APPR and PLAP configuration is higher then in the previous marketplace configuration.

When comparing the different pricing algorithms, we can see that the GT pricing algorithm gains the highest profit of all the different InfoCenter configurations. When analyzing the different pricing algorithm effects on the InfoCenter, we can look at two cases: 1) when the InfoCenter approaches the buyers (i.e., APPR and PLAP) and 2) when the InfoCenter does not approach them (i.e., NO AI and PLAN). In the first case, when the InfoCenter approaches the buyers, then the InfoCenter knows what information will have the highest profit. Therefore, the best pricing algorithm will be the one that will enable the InfoCenter to set the maximum price for the information requested by the buyers. Those algorithms are GT and MY, because they are aware of the prices that the buyers are willing to pay. The DF algorithm, on the other hand, is not aware of buyers' demand, and therefore it will gain less profit in those cases.

In the second case, when the InfoCenter does not approach buyers, then InfoCenters need to find the information with the highest profit by trial and error. Therefore, in this case the profit depends on how well the pricing algorithms deal with errors. The GT and the DF pricing algorithms are influenced less from the prices that the buyers are willing to pay, and therefore they deal better with failures. On the other hand, the MY algorithm is influenced more by the prices that buyers are willing to pay, which will lead the InfoCenter that uses it to gain less profit.

In summary, we can say that the DF algorithm gains more from planning than from approaching buyers. This is because it does not gain the profit possible from offering information that can be sold at a high price. The MY and the GT algorithms gain more from approaching buyers, while planning will increase their profit even more.

Homogeneous InfoCenters

When comparing the AI techniques' effect on the three homogeneous InfoCenters, we can see a similar effect to the market with a single InfoCenter. In other words, the InfoCenter will gain the highest profit when approaching buyers in order to understand their needs and then applying planning

	Sellers Algorithm		
Market configuration	DF	GT	MY
No AI	0.15	0.29	0.79
Planning	0.15	0.42	0.96
Approacing buyers	0.55	1.61	2.34
Planning + Approaching Buyers	0.47	2.14	2.41

Table 4.16: Three Homogenous InfoCenters' average profit when using different AI techniques

in order to use the InfoSPs' services wisely. The InfoCenter will gain more from approaching buyers, than from using planning, while the lowest profit will be obtained when none of those techniques is used. As can be seen in Table 4.16, the average profit of the homogeneous InfoCenters is smaller compared to the profit of the single InfoCenter. This is because the single InfoCenter was a monopolist InfoCenter, while the three homogeneous InfoCenters are not. When the InfoCenters are using the MY algorithm and they are not approaching buyers (i.e., NOAI and PLAN), then the three homogeneous InfoCenters will gain higher average profit than the single InfoCenter. As we mentioned before, the MY algorithm has the larger effect on the profit from the failures of trying to guess the information that buyers are interested in. But when three InfoCenters are trying to guess this information, then the possibility that one will guess it is increased, and therefore the average profit will increase, too.

When comparing the different pricing algorithms, as shown in Table 4.16, the MY algorithm will gain the highest profit, followed by the GT algorithm, and the DF algorithm will gain the lowest profit. In this market configuration, the pricing algorithm needs to handle the fact that there are other InfoCenters that sell the same information, in addition to taking advantage of different AI techniques. The MY algorithm handles both tasks well, and that will enable it to gain the highest profit.

Heterogeneous InfoCenter

In the heterogeneous configuration the effect of the different AI techniques is similar to their effect in the previous configurations. That is, the InfoCenters (both the single InfoCenter and the other four InfoCenters) obtained the highest profit when approaching buyers and then using planning. The InfoCenters that Approached buyers obtained higher profit than the InfoCenters that used planning.

We expected that the single InfoCenter will gain the highest profit when

InfoCenters' Configurationa		Sellers' Algorithm					
		DF		GT		MY	
1 IC	4 IC	1 IC	4 IC	1 IC	4 IC	1 IC	4 IC
NOAI	NOAI	0.09	0.09	0.86	-0.02	-0.47	0.05
NOAI	PLAN	-0.03	0.10	-0.30	-0.02	0.10	0.48
NOAI	APPR	0.09	0.26	0.05	0.76	-0.26	1.72
NOAI	PLAP	0.04	0.32	-0.24	1.52	-0.29	1.27
PLAN	NOAI	0.13	0.10	-0.08	0.40	-0.12	-0.12
PLAN	PLAN	0.04	0.21	0.38	0.08	-0.12	0.35
PLAN	APPR	0.05	0.22	-0.11	1.37	-0.32	1.46
PLAN	PLAP	0.06	0.33	-0.15	0.80	-0.41	1.72
APPR	NOAI	0.54	0.16	1.07	0.14	2.92	-0.05
APPR	PLAN	0.81	0.04	1.82	0.28	3.33	0.02
APPR	APPR	0.79	0.14	2.77	0.89	3.29	0.72
APPR	PLAP	0.83	0.19	3.35	1.05	3.16	0.65
PLAP	NOAI	0.78	0.03	1.03	0.13	3.28	-0.41
PLAP	PLAN	0.47	0.15	1.81	0.27	3.28	0.18
PLAP	APPR	0.55	0.21	3.03	0.78	2.95	0.81
PLAP	PLAP	0.77	0.23	3.03	0.55	4.01	0.78

Table 4.17: Heterogenous InfoCenters' average profit when using different AI techniques

it uses planning and approaches buyers when the other four InfoCenters are not approaching buyers. This is because, in that case the single InfoCenter will be the monopolist seller of the information requested by buyers. Though there are cases that it occurs, there are also cases when it does not occur. For example, we can look at Table 4.17 on the single InfoCenter that uses the MY pricing algorithm and uses both AI techniques: planning and approaching buyers (i.e., PLAP). This InfoCenter gains 3.28 when the other four InfoCenters use planning (i.e., PLAN) or use no AI technique (i.e., NOAI). The single InfoCenter decreases its profit when the other four InfoCenters approach buyers (i.e., APPR) and therefore the four InfoCenters offer the high demand information, too. On the other hand, the single InfoCenter achieves the highest profit when the other four InfoCenters approach the buyers and use planning (i.e., PLAP). Therefore, if the decrease in the profit in the first case occurred because the other InfoCenters offered the same information as the single InfoCenter, then why do we see an increase in profit in the second case?

The asnswer is a little complicated. The single InfoCenter will have an advantage in a market where the other four InfoCenters do not approach buyers. Then it can offer the desired information and sell it at a monopolist price. Nevertheless, the other four InfoCenters will start to offer that information sometime, and will create price competition over the price (though it will take the four InfoCenters more time to offer the desired information than if they would have approached the buyers). Since there are four InfoCenters, then the time that it will take for one of them to offer the desired information may not be that long. Therefore, the advantage of the single InfoCenter that approaches buyers is not that significant in a market where the other four InfoCenters do not approach buyers.

When comparing different pricing algorithms, the MY obtained the highest profits, the GT followed after it, and the DF obtained the lowest profit. The reason, like in the homogenous market, is that the pricing algorithm needs to handle well both competition over price and to efficiently use the advantage that the AI techniques enable. The MY pricing algorithm enables it to handle both aspects well.

Chapter 5

Summary and Conclusions

In this thesis, we have examined the role of InfoCenters, value-added information middle-men, in information marketplaces. In the simulations presented in the thesis, we implemented the following algorithms for pricing: the MY algorithm sets the price to the myoptimal price, the GT algorithm sets the price to one of the mixed equilibria prices, and the DF algorithm increases or decreases the price depending on the profit levels. Here, we will first present the results and conclusions when InfoCenters operate as sellers' assistants, then, the results and conclusions when InfoCenters operate as autonomous agents. We shall conclude by discussing how AI techniques can benefit InfoCenters.

In summary, the existence of InfoCenters in a marketplace creates a win-win-win situation. Buyers benefit because they can get focused information for their needs. When InfoCenters operate as sellers' assistants, then the sellers benefit because they increase their profit. When InfoCenters operate as autonomous agents, then the sellers benefit because they have additional buyers (i.e., the InfoCenters).

The InfoCenter goal was to be profitable. They succeed at that task, and they can additionally increase their profit by using AI techniques, including approaching buyers in order to understand their needs, and using planning in order to use the InfoSPs' services wisely.

5.1 InfoCenters Operate as Sellers' Assistants

In this section, the InfoCenters operate as sellers' assistants in order to enable sellers to use the advanced capabilities offered by InfoCenters. As we showed in our experiments, the sellers increased their profit when they used the InfoCenters' capabilities.

In the homogeneous market, the highest profit was obtained when using switching. When the InfoCenters cooperate and switch information, they reduce the price war by cooperating and have the ability to switch to more profitable information products. When the InfoCenters manipulate information by approaching InfoSPs, they can sell new information. Since other InfoCenters will offer that information as well, then a price war will occur and will decrease the profit of that information. Therefore, the homogeneous InfoCenter will gain more from reducing price wars and the ability to switch to more profitable information products, rather than introducing new information.

In the heterogeneous market, we have two groups, the single InfoCenter and the other four homogeneous InfoCenters. The single InfoCenter gained the highest profit when it approached InfoSPs in order to manipulate information. The InfoCenter in the heterogeneous market is the only one that can offer the new information. Therefore, the InfoCenter will gain most from offering the new information and selling it at a monopolist price. The other four homogeneous InfoCenters, similar to the InfoCenter in the homogeneous configuration, gained the highest profit when using the switching capability.

5.2 InfoCenters Operate as Autonomous Agents

Sellers benefit from the existence of InfoCenters in the marketplace. Their average profit does not change, even though they sell information to InfoCenters at a discount. InfoCenters are additional buyers, which enable sellers to sell more information and increase their total profit. Sellers gain highest profits when applying the DF algorithm in all marketplace configurations. The MY and GT algorithms have perfect knowledge of other sellers' prices and buyer demand. They use that knowledge in order to set the best price, when treating InfoCenters as regular buyers. The DF algorithm, on the other hand, does not have perfect knowledge of the market, and it reacts to market demand. In a marketplace where there is high demand, the DF algorithm will cause sellers to raise their prices. Therefore, sellers may not have the most competitive prices, but they will have higher profits, since they sell larger amounts of information.

Buyers benefit from the existence of InfoCenters, because InfoCenters can offer additional information that was not offered previously by sellers. That information may be more relevant, and in that way buyers get more for the money they pay.

InfoCenters in the e-marketplace gain positive profits. An InfoCenter will prefer to follow the MY and GT algorithms over the DF algorithm. Those algorithms have knowledge of the other seller and InfoCenter prices, and of buyer preferences. They can use that knowledge in order to set the best prices for the new information they offer.

There was no payment method that InfoCenters will prefer to use at all times in all configurations. But in most cases, they will benefit most by implementing the full price (FP) payment. In that case, the InfoCenter chooses the cheapest seller each time it buys information. Implementing any other payment method makes it guarantee to buy large amounts of information from a specific seller, and to get a discount in a return, but to lose out on possibly cheaper sellers in the future. In other words, an InfoCenter benefits more from the price war between sellers, than from the discount that the sellers offer.

The existence of InfoCenters in the marketplace did not affect price behavior. This is because InfoCenters bought the information offered by sellers and sold new information. Therefore, sellers had additional buyers (i.e., the InfoCenters), and the InfoCenters were the sellers of the new information.

When we compared the different discount methods that can be used when an InfoCenter buys a large amount of information from a seller, we found that the seller will gain the highest profit when the discount is higher. The InfoCenter will gain the highest profit when the discount is lower. Therefore, sellers gain more when selling their information with lower prices to selected customers, while those customers preferred higher prices. This is because a seller benefits from selling to an InfoCenter that buys a large amount of information, even if it sells it at a lower price. The InfoCenter, on the other hand, will prefer to buy the information at higher prices, because that will enable it to sell the new information with higher prices as well.

5.3 InfoCenters Use AI techniques

InfoCenters can increase their profit significantly when applying AI techniques. As the task of finding a profitable niche of information gets harder, then approaching buyers in order to understand what information they need becomes more important. Since Brooks et al. [BDD00] mentioned that the task of finding such a niche is hard, we expect that InfoCenters will use that technique.

The effectiveness of using planning in order to choose wisely the InfoSPs' services gets more important when the number and variety of services in the market increase. In our experiment, with two types of services that each were offered by three InfoSPs, we explored enough variety to enable InfoCenters to gain profit from using planning. In real marketplaces, we can expect a larger number of InfoSP services, and therefore we believe that InfoCenters will benefit even more from using planning.

Furthermore, using several AI techniques will increase the profit even more. As we have shown in our experiments, when InfoCenters used both techniques they benefited from both of them, and therefore gained the highest profit. Therefore, we can expect that InfoCenters will benefit from using several AI techniques in order to increase their profit.

Chapter 6

Future Work

One of our results showed that InfoCenters could benefit more from paying the full price, without being committed to a certain seller. Therefore, it would be interesting to check if InfoCenters will gain higher profits when they could subscribe to several sellers at the same time.

When InfoCenters operate as sellers' assistants, we observed that the highest profit in the homogeneous market was obtained when they used Switching of information. In the heterogeneous market, the single InfoCenter obtained the highest profit when it manipulated information. Therefore, we might expect that InfoCenters that operate as sellers' assistants will obtain the highest profit when implementing both of those capabilities. We leave this, however, for future work.

In this thesis, the InfoSP agents offered their services at a fixed price. Like the sellers and the InfoCenter agents, the InfoSPs can also (in theory) apply pricing algorithms for their services. We can explore how those pricing algorithms will effect the marketplace and the other agents' behavior.

In this thesis, we assumed that privacy issues were handled. But as of today, there are no complete solutions for illegal copying and distribution of information. Those issues need to be handled in information e-markets in order to enable them to work properly. Therefore, research on privacy issues is certainly needed.

Anther issue that needs to be handled is the question of the communication protocols between different agents in the e-market. In this research, we simplified the communication, by using a 'broker' agent that enables communication between buyers and sellers or InfoCenters. We also used a similar idea for communication when the InfoCenters approached the buyers. We exploited the fact that we developed all agents in the market, and we could ensure that they would communicate properly. Further investigation of different protocols needs to be done, in order to define a standard that can be used in e-markets that contains millions or bilions of agents.

The goal of this research was to explore how AI techniques will influence the InfoCenters' behavior and profits. In this thesis, we have started to explore this issue, but further investigation of additional AI techniques can be carried out — for example, information sharing between the InfoCenters of different InfoSP services or of buyers' demands. We used a naive planning alogorithm, because the number of operations (i.e., InfoSPs) and elements (i.e., information products) was small enough. Better planning algorithms would need to be used in real e-markets where the number of InfoSPs and information products is larger. This and other AI techniques and algorithms can help InfoCenters in information e-markets. Therefore, further investigation of those issues is needed.

Bibliography

[Ama] Amazon. http://www.Amazon.com.

[BB97] Joseph P. Bialey and Yannis Bakos. An exploratory study of the emerging role of electronic intermediaries. In *International Journal of Electronic Commerce*, March 1997.

[BB00] Y. Bakos and E. Brynjolfsson. Bundeling information goods: Prices, profits and efficiency. In *Internet Publishing and Beyond: The Economic of Digital Information and Intellectual Property*, MIT Press, Cambridge, Massachusetts, 2000.

[BDD00] C. H. Brooks, E. H. Durfee, and R. Das. Price wars and niche discovery in an information economy. In *ACM Conference on Electronic Commerce*, 2000.

[BJ83] K. Burdett and K. L. Judd. Equilibrium price dispersion. In *Econometrica*, pages 51(4):995–969, July 1983.

[cM96] A. chavez and P. Maes. Kasbah: an agent marketplace for buying and selling goods. In *the first International Conference on the Practical Application of Inteligent Agents and Multi-Agent Technology*, London, UK, April 1996.

[DHKT01] R. Das, J. E. Hanson, J. O. Kephart, and G. Tesauro. Agent-human interactions in the continuous double auction. In *Proceeding of the International Joint Conference on Artificial Intelligence (IJCAI-01)*, Seatle, USA, 2001.

[Dia71] P. Diamond. A model of price adjustment. In *Economic Theory*, pages 3:156–168, 1971.

[DSW97] K. Decker, K. Sycara, and M. Williamson. Middle-agents for the internet. In *Proceedings of the 15th International Joint Conference on Artificial Intelligence*, Nagoya, Japan, 1997.

[eBa] eBay. http://www.eBay.com.

[FIP] Object Management Group web page. http://www.FIPA.org.

[gar] gartner. http://www.gartner.com.

[GK99] Amy Greenwald and Jeffrey O. Kephart. Shopbots and pricebots. In *Proceedings of the Internation Joint Conference on Artificial Inteteligence (IJCAI-99)*, Stokholm, July 31 - August 6 1999.

[HS96] E. Hopkins and R. M. Seymour. Price dispersion: An evolutionary approach. In *Unpublishe Manuscript*, October 1996.

[IDC] IDC. http://www.IDC.com.

[Kam] Kamoon. http://www.Kamoon.com.

[KF00] Jeffrey O. Kephart and Scott A. Fay. Competitive bundling of categorized information goods. In *ACM Conference on Electronic Commerce*, pages 117–127, 2000.

[KG99] Jeffrey O. Kephart and Amy Greenwald. Shopbot economics. In *Proceedings of the Fifth European Conference on Symbolic and Quantitative Approaches to Reasoning with Uncertainty*, London, UK, July 1999.

[KGMP97] Steven Ketchpel, Hector Garcia-Molina, and Andreas Paepcke. Shopping models: A flexible architecture for information commerce. In *Proceedings of Digital Libraries*, 1997.

[KHG00] Jeffrey O. Kephart, James E. Hanson, and Amy R. Greenwald. Dynamic pricing by software agents. *Computer Networks*, 32(6):731–752, May 2000.

[MRM00] J. Morris, P. Ree, and P. Maes. Sardine: Dynamic seller strategies in an auction marketplace. In *Proceedings of the Conference on Electronic Commerce (EC '00)*, Minneapolis, MN, October 17-20 2000.

[OMG] Foundation for Intelligent Physical Agents web page. http://www.OMG.org.

[PDB98] S. Park, E. H. Durfee, and W. P. Birmingham. Emergent prototypes of a marketplace digital library with strategic agents. In *Proceedings of Third International Conference on Multi-Agent Systems*, pages 230–237, July 1998.

[SS82] S. Salop and J. Stilitz. A theory of sales: A simple model of equilibrium price dispersion with identical agents. In *American Economic Review, Papers and Proceedings*, pages 72(5):1121–1130, December 1982.

[Tir88] J. Tirole. The theory of industrial organization. In *The MIT Press*, Cambridge, MA, 1988.

[Var80] H. Varian. A model of sales. In *American Economic Review, Papers and Proceedings*, pages 70(4):651–659, September 1980.

[WS79] L. L. Wilde and A. Schwartz. Equilibrium comparison shopping. In *Review of Economic Studies*, pages 46:543–553, 1979.