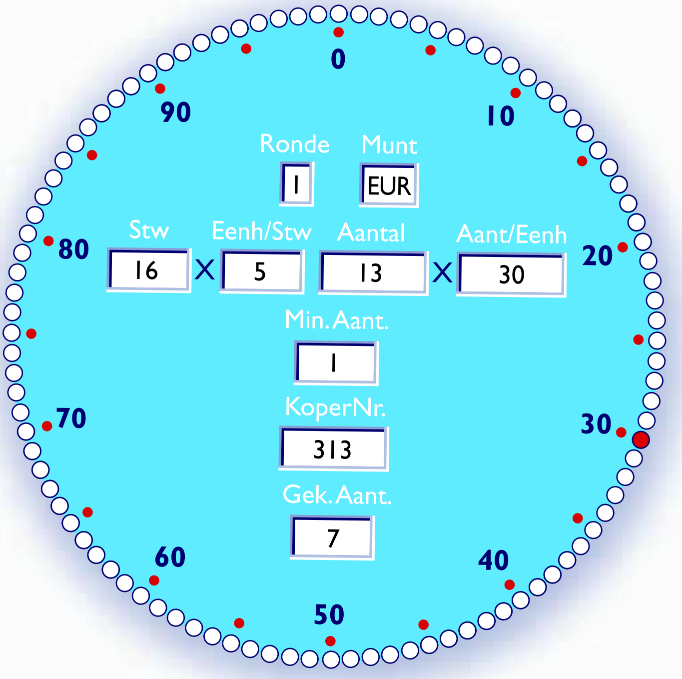
OTTO R. KOPPIUS

Information Architecture and Electronic Market Performance



INFORMATION ARCHITECTURE AND ELECTRONIC MARKET PERFORMANCE

INFORMATION ARCHITECTURE AND ELECTRONIC MARKET PERFORMANCE

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Promotoren:
Prof.mr.dr. P.H.M. Vervest
Prof.dr.ir. H.W.G.M. van Heck

Overige leden:
Prof.dr.ir. J.A.E.E. van Nunen
Prof.dr. M.H. Rothkopf
Prof.dr. K. Kumar

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First, I am grateful to my supervisors and the Erasmus Research Institute of Management for taking a chance with someone who did not quite fit the profile of a prototypical management Ph.D. student. From the first day I arrived here, I've felt quite at home. To no small extent can this be attributed to the fellow Ph.D. students that started at the same time, several of which have become good friends. Particularly with my roommate for the first six months, Leon Peeters, we joked around so much that I dare not think what had happened to our productivity if we had not gotten separate offices. As a group, the 'Class of 97' developed a cohesion that provided a lot of laughs during the highs and intellectual and emotional support during the lows, thanks! It looks like the prediction we made on a winter night in The Hague late 1997 was 100% accurate. Also, special thanks to AnneMarie Stolkwijk and Tineke van der Vhee for taking good care of us Ph.D. students.

Another important factor that made me feel at home, was the pleasant working environment with colleagues at the department of Decision and Information Sciences and the many opportunities the department provides. This was one of the reasons why the decision for me to continue as an assistant professor here was an easy one to make.

The main reason to stay on though, was that I would be able to continue my collaboration with Eric van Heck. To have a supervisor who allows you such freedom to pursue your own research angle is unusual. To have one who supports his Ph.D. students the way he does (a lot of it behind the scenes where he thinks we will not notice, but we most certainly do!) is already very rare. But to have one with whom you also work together so productively and pleasantly is unique indeed. I look forward to continuing our joint work for many more years to come.

Sometimes while doing your research, you feel like what you are doing is insignificant, but whenever I heard my other supervisor, Peter Vervest, talk about my research, I came away energized by his enthusiasm. Even though I may not always have agreed with his suggestions, they have always stimulated my thinking. His ability to see the practical side of academic research is a quality that I will try to emulate.

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Otto Koppius
Rotterdam, March 2002

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CHAPTER 1 : INTRODUCTION AND RESEARCH QUESTIONS

1.1 Markets, auctions and the Internet

Markets are social institutions that facilitate exchange by means of competition (Coase, 1988; Weber, 1978 [1922]; Swedberg, 1994). The primary goal of a market is to solve the problems of resource allocation (who gets what) and price determination (at which price). Explicit resource allocation is necessary when at a certain price, there is more demand than supply and therefore not all potential buyers can be satisfied. In a hierarchical setting, resource allocation occurs by command from higher levels in a hierarchy; in a market, it occurs through competition among traders. Price determination is necessary to solve the fundamental problem that the seller faces: how much is this product or service worth? The answer to this question determines how much the buyer pays and how much the seller receives. To solve these problems of resource allocation and price determination, thereby achieving the goal of a market, potential buyers and sellers compete for transaction opportunities by exchanging information. They exchange information about what they want to buy or sell, how much they are willing to pay or accept and other terms of the trade until a transaction is made or a party decides to leave the market. These processes of information exchange will be the common thread throughout this dissertation.

The information exchange in markets differs in how structured the process is. Most bargaining situations are highly unstructured, whereas auctions are highly structured. See for instance the following definition of an auction that is adopted here: "An auction is a market institution with an explicit set of rules determining resource allocation and prices on the basis of bids from participants." (McAfee and McMillan, 1987).

Information exchange in an auction occurs through the bids of the participants. Bids state their current willingness-to-pay for the object that is being auctioned[1]. The explicit rule of the auction mechanism determines who wins the auction at

[1] This is for the case of a forward auction where bidders are buyers. In a reverse auction, the bidders are sellers and their bids state their current willingness-to-accept a certain price for their goods or services.

what price, based on the bids submitted. Four basic auction mechanisms, described here in the case of the sale of a single object are (Vickrey, 1961; McAfee and McMillan, 1987):

- *English auction*: The auctioneer starts at a low price and bidders keep submitting bids that are higher than the current highest bid until no one is willing to bid any higher and at that point the current highest bidder wins the auction at that price.
- *Dutch auction*: The auctioneer starts at a very high price and continuously lowers the price (quite often through the clock-based mechanism used in the Dutch flower auctions where this auction derives its name from) until one bidder accepts that price, who then wins the auction and pays that price, i.e. his bid.
- *First price sealed bid auction*: All bidders independently submit one bid to the auctioneer. The highest bidder wins and pays his bid.
- *Second price sealed bid auction (or Vickrey auction)*: Like in the first price sealed bid auction, all bidders independently submit one bid to the auctioneer and the highest bidder wins. However, he does not pay the price of his own bid, but the price of the highest rejected bid, i.e. the second-highest bid.

Each of these auction mechanisms solves the problems of resource allocation and price determination in its own way with its own information exchange processes, which can result in different auction outcomes, thereby making the choice for a specific auction mechanism non-trivial (McAfee and McMillan, 1987).

One aspect that all auctions have in common though, is that they are particularly suited to instances where the price determination problem is difficult; i.e. there is significant uncertainty over the actual value of the object to be transacted. For the seller, a pragmatic solution to this problem would be to simply set an arbitrary fixed price for whomever is willing to pay that price. However, this does not really answer the question of how much the object is worth and it is quite likely that the seller could have been better off transacting at a different price. Perhaps another buyer was willing to pay a lot more, but did not find out that it was for sale until the first buyer had bought it. In that case, both the seller and this new buyer would have liked to transact at a higher price if that meant that the new buyer would get what he was looking for. Or in a different situation there might be another buyer

who would like to buy the object as well, but at a lower price than the seller initially set. If that buyer's willingness-to-pay is above the price that the seller would be willing to accept, both parties would have been better off if that transaction had taken place. To find out more precisely what something is worth, it is necessary to get all potential buyers together and let them compete for it. This is by no means trivial: buyers and seller(s) have to assemble in one place. Furthermore, they have to spend time figuring out who is going to get what at which price and this time may be constrained. In other words, there are costs associated with operating such a market mechanism, i.e. transaction costs (Coase, 1937).
This means that another necessary condition for an auction to be practical (other than uncertainty over the value) is that the transaction costs for buyer and seller are small enough compared to the additional benefit they get from holding an auction instead of setting a fixed price. Traditionally, this meant that auctions were used primarily for unique, high-value items such as paintings and construction projects, or collectibles or when there are commodities with large fluctuations in supply and/or demand, such as flowers, fish and other agricultural products (Smith, 1989). In the high-value-items case, the potential extra gains for the seller of finding a bidder who is willing to pay a high price outweigh the seller's transaction costs and the high value to the buyer outweighs his transaction costs. In the supply/demand-fluctuations case, the transaction costs for a single, isolated auction would be too large compared to the modest value of agricultural products, but holding many auctions in a short period of time lowers the transaction costs for buyers enough to make participation feasible.

This is where the Internet offers great benefits. With its open standards, relatively low entry barriers and low cost of communication, the Internet makes gathering people in one place a lot cheaper. Instead of having to physically gather in one place to bid, bidders can now gather electronically via newsgroups, email lists and webpages. Electronic bidding removes a large part of the transaction costs associated with traditional auctions. As a consequence, auctions have sprung up everywhere. The posterchild of electronic auctions is eBay. Having started in 1995, eBay now hosts over 4 million auctions each day (eBay, 2002) and is one of the few structurally profitable Internet startups. One reason why eBay has grown so large is that they have tapped into two markets that previously were not there or operating only on a very small scale. One is the market for second-hand goods and collectibles. This was a market originally confined to local newspapers, garage sales and fairs, but eBay has broadened the reach of this market to in principle anyone in the world with an Internet connection. Of course many practical obstacles to trading globally such as physical shipping costs and import taxes remain largely unaffected by the Internet (Mol and Koppius, forthcoming). The second major new market is the market for surplus inventory. Products for which there is little demand locally at a certain price can now be auctioned to people in other places where there still is demand for that product at that price. Both these markets could not have operated on this scale without the cheap, global communication that the Internet provides.

Although eBay focuses particularly on the consumer-to-consumer (C2C) market and the business-to-consumer (B2C) market, in the last two years the business-to-business (B2B) market has grown significantly. Companies such as FreeMarkets (www.freemarkets.com), ChemConnect (www.chemconnect.com), VerticalNet (www.vertical.net), FastParts (www.fastparts.com), e-Steel (www.e-steel.com) and numerous others have set up auctions aimed at improving the purchasing processes in the supply chain. Although such ventures are receiving a lot of enthusiasm in the business press (and for a while on the stock market as well), it is an open question what auction models will be successful in the long run, because the consequences for the various stakeholders involved of using electronic auctions are unclear. This is particularly important in the B2B context where there is repeated interaction between the participants and also the stakes are much higher than in the consumer market. As an example of the unclear consequences, one could say that a lower price may benefit the buyer initially, but it may also reduce the supplier's willingness to invest in a relationship with the buyer, which in turn may offset the lower price in the long run (Jap, 2000; Kern, Willcocks, and van Heck, 2002).

Another example deals with the almost global nature of the Internet. Because of this, using an electronic market may increase the chance of dealing with an international buyer or seller. This in turn may give rise to a number of other issues such as problems and risks associated with international payments, transportation, communication as well as regulatory constraints (Mol and Koppius, forthcoming). How these effects balance out in practice is still unclear.

There is an emerging body of literature on electronic markets and auctions that is beginning to address these and other issues. An electronic market is defined as a market that uses electronic information and communication technology (ICT) to support exchange processes, where ICT is defined as "the infrastructure that makes it possible to store, search, retrieve, copy, filter, manipulate, view, transmit and receive information." (Shapiro and Varian, 1999, p.8). Thus, any market has a type of ICT associated with it, but electronic markets theory (EMT) focuses specifically on the role of electronic ICTs. Three central questions of electronic market theory are:

- How does ICT influence the choice of coordination mechanism? Will markets become more common or will hierarchies prevail or networks? (Malone, Yates and Benjamin, 1987; Clemons, Reddi and Row, 1993; Bakos and Brynjolfsson, 1993; Brynjolfsson, Malone, Gurbaxani and Kambil, 1994; Holland and Lockett, 1997)
- How do electronic markets differ from traditional markets? Will prices increase or decrease? Will buyers become more or less price-sensitive? Will electronic markets exhibit more or less price dispersion? How much does reputation matter in an electronic market? (Bakos, 1991, 1997; Lee, 1998; Klein and O'Keefe, 1999; Brynjolfsson and Smith, 2000; Degeratu, Rangaswamy and Wu, 2000)
- What new market institutions can be created using ICT? Who benefits? What motives are there for adoption? (Clemons and Weber, 1996, 1998; Kambil and van Heck, 1998, 2002; Klein, 1997, 2000; Teich, Walllenius and Wallenius, 1999; Milgrom, 2000; Grewal, Comer and Mehta, 2001)

As with any emerging area of research, the questions far outnumber the answers, so there is significant scope for new contributions. This dissertation aims to contribute to the last two categories of that emerging body of knowledge through three independent studies investigating electronic auctions and using multiple methods. The common thread linking these studies is a focus on the processes of information exchange described in the beginning of the section. This leads to the introduction of the concept information architecture of the market: *the information architecture describes what type of information (that is relevant to trader's decision processes) is available to whom, or when and how it becomes available to whom during the market process.* It thus accommodates both information that characterizes the market as a whole (for instance how products are described to the traders) as well as information that is specific to a particular market process (such as the revelation of bids during an auction). The concept of information architecture, although independently developed here and specifically for the context of markets, has a long history in the literature on information systems development. For example, in the ISP method (Martin, 1982), the information architecture describes the relationship between business activities (functions and processes) and data (entity types) and how different departments are involved (Bots et al., 1999, p. 748). A common way to operationalize such an information architecture is via a C-U-matrix (Martin, 1982, p.65) that describes which business processes create (C) which data and which business processes use (U) which data. That approach is conceptually similar to the definition of information architecture employed here, as both concepts deal with the availability of data to the various parties or processes involved, but there are some differences. In the IS development approach, there is a single information architecture based on the underlying business model, which is assumed to be relatively stable (Martin, 1982, p.18). It is a blueprint that the information system has to conform to: the information that business processes need to use, has to be available to them, so the information system has to ensure that the information flows from the place it is created to the place(s) it is used.

Information architecture, the way it is employed in this thesis, allows the market designer to determine who will get to use certain information. This makes the information architecture open to design considerations, based on the goals of the market designer. In this thesis it is investigated how different information architectures affect the designer's goals; in this case various market performance measures.

1.2 Research questions and objective

When investigating electronic markets, a distinction can be made between the concepts of market process, market outcome, market performance and market success (see fig. 1.1 for how they are related). Market process is defined as the processes of information exchange that occur in the market (for instance the bids in an auction).

Market outcome is the set of transactions that arises as a result of this market process. Note that both the definitions for market process and market outcome are purely descriptive, without the normative implications that the concept of market performance entails. Market performance is based on a set of performance criteria by which the market process and market outcome are judged. Many performance

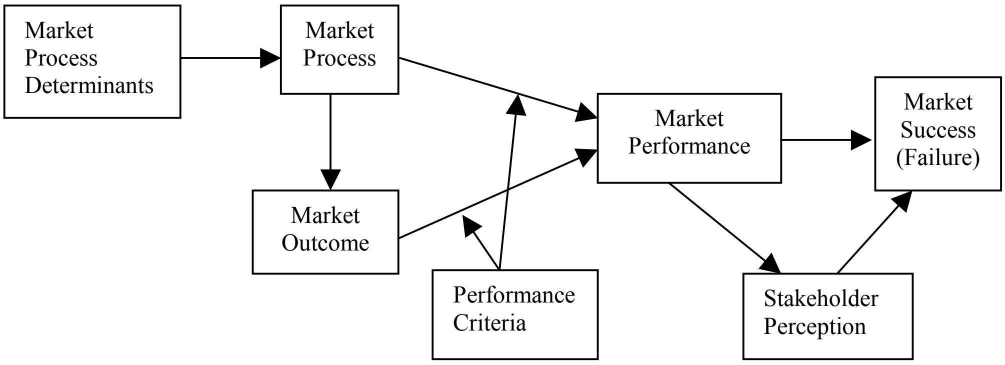

Figure 1.1 Relationship between market process, outcome, performance and success

criteria exist, such as allocative efficiency, informational efficiency, market volume or speed of convergence of the market process (O'Hara, 1995). Some of these may be conflicting, which makes an unambiguous interpretation of 'better' market performance difficult.

Furthermore, different stakeholders in a market may have different goals and therefore use different performance criteria (Kambil and van Heck, 1998). So in addition to a direct relationship between market performance and market success, an important indirect relationship exists that depends on how the various stakeholders perceive market performance relative to their interests. It is the confluence of these stakeholder interests that eventually determines whether or not the market is viable in the long term, i.e. its success or failure (Kambil and van Heck, 1998).

There are a number of factors that influence market processes (i.e. the market process determinants), such as for instance the (in)balance between supply and demand, the numbers of buyers and sellers in the market, the willingness-to-pay and willingness-to-accept of each of these buyers and sellers, but also factors that are not purely economic, such as the degree to which buyers and sellers know and trust each other and the regulatory framework of the market.

ICT is another relevant factor for the analysis of markets and it can affect market processes in two general ways. The *direct* effect occurs because ICT has a direct impact on the information exchange processes, for instance the cheaper and faster communication that email allows compared to a fax. The *indirect* effect occurs when a factor that has a direct effect on the market processes is affected by ICT, i.e. that factor is a mediating variable (Baron and Kenny, 1986) for the effects of ICT. Information architecture is an example of such a mediating variable: different ICTs can cause changes in what types of information are available to be exchanged. For instance email does not allow for intonation to be communicated as well as over the phone, which will affect the information exchange processes because now certain information is lacking that could be relevant to interpreting the message. In this case, the immediately preceding cause is not the different ICT, but the different information architecture, which in turn is caused by the different ICT.

Several studies exist that start at the right hand side of figure 1.1 and try to distill success or failure factors for electronic markets (e.g. Kambil and van Heck, 1998; Pisanias and Willcocks, 1999). This dissertation takes a complementary approach by starting at the left hand side of figure 1.1. As literature review in the second chapter shows, most research on electronic market to date has been done with a focus on the reduced transaction and search costs, caused by a change in ICT. This is an example of the direct effects of changing ICT. Indirect effects have received relatively less research attention thus far, largely because the intermediate variables, through which ICT would have its indirect effect, have been left unspecified. This thesis contends that the information architecture of the market is such an intermediate variable. A change in ICT affects the information architecture of the market and this will affect market process, outcome and performance. This leads to the following overall research question (ORQ):

(ORQ) How does ICT influence the information architecture of the market and how does this affect electronic market process, electronic market outcome and electronic market performance?

This dissertation answers this question in two complementary ways. The first way is to investigate a particular empirical setting and answer the research question for that specific market and ICT. This is done in three separate empirical studies. The second way to answer the research question is by synthesizing and generalizing the empirical findings at the end of the dissertation into a conceptual model of electronic markets that relates the constructs from the ORQ.
The main objective here is to show that focusing on the information exchange processes in the market, and in particular the concept of information architecture,

is a fruitful way to analyze markets, especially when dealing with the effects that ICT has on markets. The thesis will attempt to achieve this goal by conducting three separate studies, each investigating a *specific* form of ICT in a *specific* market (in each case a type of auction, an important subset of markets). Although each study has its own specific research question, they all will be investigated using this particular lens. A secondary objective is to make an analytical generalization of the findings (Yin, 1994) as the first step towards an integrative model of electronic markets.

As seen from the definition, the information architecture governs the set of information that is relevant to the trader's decision processes. Within that information set, three categories of information can be distinguished:

1. *Product quality information:* information about the properties of the object that is to be traded that allows traders to infer product quality.
2. *Market process information:* transaction-specific information, such as the highest bid or trader identity.
3. *Market state information:* public, non-transaction, market-related information, such as the number of traders or the sound level in the market (Coval and Shumway, 2000).

Each separate study deals with one or more of the information categories above and the research questions of these studies are described in more detail below. One of the things that an electronic market entails is that products now have to be represented digitally instead of physically. This can mean that potential buyers have less information available to them to ascertain product quality and thus to determine whether or not the product fits their needs. The consequences of this change in product quality information will be investigated in the first study at a large Dutch flower auction, which leads to the first detailed research question (DRQ):

(DRQ1): How does reduced product quality information affect market process, market outcome and market performance in an auction?

Another change in an electronic market compared to a traditional market is that buyers no longer physically need to gather in one place and instead they participate electronically using a computer at their home or office. This represents a reduction of search and switching costs for buyers and sellers (an example of the direct effects of ICT). However, this reduction potentially comes at a cost: not only may there be reduced quality information due to digital product representation like in the case described above, but because traders no longer see or hear each other, they may lack information about the current state of the market (market state information). For instance, they may not know how many traders there are in the market, which affects their bidding (Engelbrecht-Wiggans, 2001; see in particular footnote 2: "…the 'different information flows' make it easier for bidders to figure things out in one auction than the other."). Another type of missing market state information may be the sensory cues that could otherwise give traders valuable information about the state of the market, such as the sound level (Coval and Shumway, 2000). This missing market state information is an example of the indirect effects of ICT on market processes. The consequences of this will be investigated in a second, separate study at the same Dutch flower auction as the first study, leading to second detailed research question:

(DRQ2): How do reduced search and switching costs and reduced market state information affect market process, market outcome and market performance in an auction?

These first two studies were designed to analyze the impact of a change in ICT on an existing auction. The general question in those studies is: what happens when a traditional auction moves towards an electronic auction? A potential effect of ICT on markets is that ICT allows the creation of new types of markets that were previously hard to implement. The third study designs such a new type of market, a multidimensional auction. Buyers generally take much more information into account in their buying decision than just price (the first two studies confirm this point as well). Price is a reflection of the underlying value drivers (Lancaster, 1966) as the buyer makes tradeoffs among such dimensions as various quality attributes, quantity, delivery time, warranty policy, in addition to price. In the vast majority of auctions currently in use, bidders only bid on price. In a multidimensional auction, bidders bid on multiple dimensions, for instance a three-dimensional auction on price, quality and delivery time. This is particularly useful in a procurement setting, where a buyer stages a reverse auction among multiple suppliers (bidders) for a contract to deliver certain goods. A specific application area is capacity auctions for commodities such as bandwidth, container

space or electricity, where the underlying dimensions are relatively easy to specify and quantify.
In a multidimensional auction, the buyer announces which dimensions are relevant to him and then lets the suppliers bid on these dimensions, instead of specifying the product exhaustively in advance. Because the buyer probably has incomplete information about what suppliers can potentially offer him on the various dimensions, fixing these in advance may result in money being 'left on the table'. This means that there are improvements possible that represent a win-win-situation for all parties involved (Bazerman, Magliozzi and Neale, 1985; Rangaswamy and Shell 1997). Making the relevant dimensions an integral part of the market process through a multidimensional auction is one way of trying to capture the potential extra value hidden in the different comparative valuations of buyers and sellers (Koppius, 1998). Preliminary empirical evidence supports this view (Bichler, 2000).

The first two studies explore the various aspects of the concept of information architecture as they highlight the importance of specific types of information for explaining market outcomes. The third study formally tests the influence of information architecture. In particular, it tests aspects of the information architecture that deal with information about the bids in the auction, a type of market process information. This leads to the third detailed research question:

(DRQ3): What is the influence of a change in the information architecture of market process information on market process, outcome and performance in an electronic multidimensional auction?

The answers to these questions should yield evidence in support of the view that is advanced here, which is that information architecture is an important determinant of market processes and that the information exchange processes in a market are a useful lens through which to study (electronic) markets.

The last part of the dissertation theorizes about the findings of the three studies and their generalization using additional literature, in an attempt to arrive at a conceptual model of electronic markets. Each link among the constructs has been empirically validated independently in one or more of the three separate studies, but the model as a whole is not empirically tested. The model is intended to provide the first step for further development and testing of electronic market theory, which should eventually explain electronic market success and failure.

1.3 Methodology

The overall methodology of this dissertation is that of multi-method research (Brewer and Hunter, 1989; Mingers, 2001). The basic idea behind multi-method research is that each research method has its strengths and weaknesses. For instance, case studies rank high on external validity (in a properly defined domain), but it is often difficult to draw causal inferences (low internal validity), whereas lab experiments rank high on internal validity, but the results may not generalize to domains outside the lab (low external validity). Multi-method research aims to strengthen the validity of the research by triangulation of methods, whereby the methods are chosen to complement each other's strengths and weaknesses.

This triangulation can take the form of simultaneous or sequential triangulation (Brewer and Hunter, 1989). In simultaneous triangulation, the researcher uses multiple methods in the same study to measure the same phenomenon (Jick, 1979; Yin, 1994). An example is to combine qualitative ethnographic evidence with quantitative social network measures in the study of technology adoption (Barley, 1986). In sequential triangulation, the results of one method are the basis for a new study of the same concept with a different method. An example is to start with an exploratory case study to develop a conceptual model of modularity that is then tested on a large sample using survey methods, such as done by Wolters (2002). Sequential triangulation best describes the approach of this dissertation.

The first two studies are primarily quantitative case studies. They were set up to investigate the effects of two new ICT-based forms of auctioning at a Dutch flower auction, using the transaction database of the flower auction. Through the course of the first study, it became apparent that the information available to the traders (or more accurately: the change in information that the new ICT-based auction form entailed) played a central role in explaining the observed effects. Therefore in the second study, which was originally intended as a test of the effects of reduced transaction costs only, information-based explanations were explicitly incorporated to explain the observed effects. Both of these case studies have the advantage of studying a real-life phenomenon in detail (Yin, 1994). The drawback is that causal inferences can only be made plausible, not proven, because it is impossible to control for all potentially relevant external factors.

This is where the third study comes in. The first two studies suggested the importance of what in the third study is more formally incorporated as the information architecture of the market. This study was a laboratory experiment explicitly designed to test information architecture as a determinant of market performance. What the laboratory setting lacks in realism, it makes up for it in internal validity, i.e. the establishment of a causal relationship, because the external factors are controlled for to a very large extent (Friedman and Sunder, 1993). The combination of these two methods means that the concept of information architecture has both high external validity -being developed from the case studies- and high internal validity -established through the experiments- (Brewer and Hunter, 1989). The methodological aspects of the individual studies will be dealt with in their respective chapters.

1.4 Scientific relevance

The first contribution of this dissertation is the identification of information architecture as an important determinant of electronic market processes, -outcome, -performance and eventually -success (although the latter is not explicitly dealt with in this dissertation). Information architecture is new in this particular form, but several aspects of it have seen significant research in the market microstructure literature and the literature on the economics of information.

On one hand, certain aspects of information architecture have been investigated in the finance literature under the heading of market transparency (see for instance O'Hara (1995), Ch.9.1), particularly the issues of publishing prices and order flow in financial markets. The concept of information architecture is more general than that however, because it also takes into account other information that is relevant to the trader's decision processes, particularly information about the traded object itself[2]. It can therefore not only apply to financial markets, but to other markets such as auctions as well.

[2] See also the following quote: "From the perspective of non-financial markets…*the exchange of non-transaction signals is critical*. In other markets, participants constantly obtain signals to determine the nature of the supply and demand curves against which they trade or compete to trade." (Coval and Shumway, 2000, p.1, emphasis added)

On the other hand, information about the traded object and particularly asymmetries thereof among buyers and sellers, is a central concept in the economics of information (see Stiglitz (2001) for an overview). This stream of literature usually conceptualizes information as an exogenous factor that then determines the phenomenon under investigation. What information architecture adds to this is endogenizing the information by explicitly recognizing the dynamics of information exchange. Information architecture also emphasizes the fact that information is a multidimensional construct in itself, because different types of information can have qualitatively different effects and conceiving of information as a single-dimensional type may not fully do justice to that fact (recent research on multidimensional screening is going in a similar direction, see for instance Rochet and Chone (1998)).

A second contribution is the development of the multidimensional auction. A handful of articles in the economic literature analytically analyzed this type of auction (Che, 1993; Cripps and Ireland, 1994; Branco, 1997), but together with the papers by Teich, Wallenius and Wallenius (1999), Bichler (2000) and Cho (2001), this is one of the first studies to *empirically* analyze a multidimensional auction. The software developed for the experiment is flexible enough to allow a wide variety of multidimensional auction mechanisms to be studied empirically.

This dissertation also makes a third contribution of a methodological nature. As Choudhury, Hartzel and Konsynski (1998) argued, case studies of individual electronic markets are necessary to get a detailed understanding of the factors that are relevant to the way an electronic market functions. At the same time however, one would like to establish a clear causality between the suggested determinant and the observed outcome. Laboratory experiments are particularly suited for this purpose (Friedman and Sunder, 1993). A multi-method research study in which the methods have complementary strengths and weaknesses is potentially stronger than a single-method study (Brewer and Hunter, 1989).

However, despite the benefits of this type of research, in the IS field (and elsewhere) such studies have been rare (Mingers, 2001). This dissertation, using a combination of case study research and laboratory experiments each with their particular, non-overlapping strengths, can be seen as an example of a multi-method research study, which will hopefully stimulate other researchers to use multi-method approaches as well.

1.5 Managerial relevance

As doing business over the Internet becomes more and more common practice, it is vital for market designers, traders and executives to have a good understanding of the issues involved (van Heck and Vervest, 1998). One set of issues revolves around the usage of electronic markets and auctions to do business between organizations. Using electronic auctions can have a variety of seemingly contradictory consequences, such as reduced prices (Bakos 1991, 1997) or increased prices (Lee, 1998). Empirical studies are necessary to not only identify antecedents and outcomes, but also to lay a foundation for testing the robustness of such results to contextual factors. Such studies will sensitize market designers to the large set of factors involved in designing a market and how those factors can affect market performance. The research in this dissertation highlights one such factor, namely the information architecture of the market. It shows that the information architecture has a significant influence on market outcome and performance. This means that explicit attention should be given to how to design the information exchange processes in a market and that information architecture becomes an integral part of a market designer's toolkit.

For individuals and organizations that are trading in electronic markets, this research shows three things. First, it emphasizes the basic point that information is a crucial part of trading in a market. Second, it highlights three different categories of information that are relevant for trading processes: product quality information, market process information and market state information. Third, and most importantly, it shows how these different types of information each affect trading processes and market outcome. Being fully aware of this will stimulate more informed decision-making in markets, leading to win-win improvements for all involved.

Another point of practical relevance is the development of a new type of auction, the multidimensional auction. A complaint often heard about conventional auctions is that they focus on price only, whereas in reality there is much more to value than just price and bidders often feel that this is not taken into account properly (Jap, 2001). Using a multidimensional auction in such cases can transform the win-lose nature of the buyer-seller relation in conventional price auctions into a win-win situation, leading to gains for all parties involved.

1.6 Structure of this dissertation

The next chapter surveys the existing literature on electronic markets to lay the theoretical background for the later chapters. Chapter 3 investigates the first research question, namely the influence of reduced quality information on bidding behavior. The empirical setting is a large Dutch flower auction that introduced screen auctioning, which replaced showing the actual flower to the bidders by showing a generic picture. This meant a loss of product quality information for the bidders. A statistical analysis of the flower auction's transaction database before and after screen auctioning shows several changes in bidding behavior, such as lower prices and increased importance of product attributes and seller reputation in determining price.

Chapter 4 investigates the second research question, namely the influence of reduced transaction costs and reduced market state information. At the same Dutch flower auction as in chapter 3, bidders had the option of bidding electronically from their home or office instead of physically being in the auction hall. This greatly reduced their transaction costs, but it also implied a loss of market state information. As those online buyers bid in the exact same auctions as the buyers in the auction hall, this provides a direct test for bidding behavior differences between online and nonline bidders. Some differences were lower prices and lower purchasing variety for online bidders.

Chapter 5 discusses problems with auctions in which bidders bid only on price. This provides the rationale for developing a multidimensional auction, in which bidders bid not only on price, but also on the value drivers such as quality, delivery time and warranty. It describes the software prototype that was built to conduct the laboratory experiments. It also introduces the concept of information architecture more formally. The relevance of this concept for market performance is tested using a series of laboratory experiments in which students bid under different information architectures. We show that the information architecture has a significant effect on two auction performance parameters, winner efficiency and Pareto optimality, thus answering the third research question.

Chapter 6 looks at the theoretical implications of the results in the previous chapters for a theory of electronic markets that builds on the empirical studies in this dissertation to create a conceptual model of electronic markets.

Chapter 7 discusses the results and limitations of the research, offers conclusions and suggests directions for further research.

CHAPTER 2 : LITERATURE SURVEY

2.1 Introduction

This chapter surveys the existing literature on electronic markets. It focuses in particular on the papers that have studied electronic markets empirically in order to get a clear picture of which issues have been debated with what result and to identify gaps in the literature. This provides part of the theoretical background for the studies in the subsequent chapters.

The literature on electronic markets is roughly divided into three streams, based on their level of analysis. The first stream analyzes electronic markets compared to other electronic coordination mechanisms. Its focus is on how ICT influences the choice of coordination mechanism, for instance the electronic markets vs. electronic hierarchies debate (Malone, Yates and Benjamin, 1987). The second stream analyzes electronic markets compared to non-electronic markets. Its focus is on how market processes in electronic markets differ from traditional markets, for instance the reduced price hypothesis (Bakos, 1991). The third stream looks at electronic markets from an institutional point of view, sometimes studied in isolation, sometimes studied in comparison to other electronic markets. Its focus is how electronic markets differ from each other (e.g. Kaplan and Sawhney, 2000) and how these differences can explain the success or failure of a new institution such as an electronic market (Alba, Lynch, Weitz, Janisziewski, Lutz, Sawyer and Wood, 1997). These three streams will be analyzed in the sections below.

2.2 ICT and the choice of coordination mechanism

The first stream of electronic markets literature investigates how ICT affect the choice of coordination mechanism. It started with the seminal work of Malone, Yates and Benjamin (1987). They offer three arguments that increased ICT use will lead to electronic markets being favored relatively more than electronic hierarchies. Their first argument is that on a general level, ICT reduces the cost of communicating and processing information, i.e. the cost of coordination. As these costs are higher in markets than in hierarchies, the absolute cost reduction will be larger in markets, thus leading to a relative shift towards electronic markets. Butler

et al. (1997) make a similar point in their discussion of interaction costs, which they estimate to be reduced by 60% on average, through use of the Web.
On a more detailed level, Malone, Yates and Benjamin observe that these coordination costs are determined in part by the asset specificity of the product (the degree to which the product can be employed outside the specifics of the current transaction (Williamson, 1985) and the complexity of product description. When both factors are high, the product is likely to be obtained through hierarchical coordination and when both factors are low through market coordination (when one factor is high and the other is low is not dealt with in their paper). They then argue that ICT-enabled flexible manufacturing systems essentially reduce the asset specificity of the product; lower asset specificity favors market-based coordination over hierarchical coordination (Williamson, 1985). Their third argument is that databases and high-bandwidth electronic communication enable markets to communicate effectively more complex product descriptions than before, thus again favoring markets over hierarchies.
Although seemingly compelling, empirical tests of this hypothesis have not yielded very supportive results. Rosenthal, Shah and Xiao (1993) investigated the chemical industry, but their evidence suggests a move towards electronic hierarchies. They explain their results by pointing to the sourcing literature, which shows an increased use of single sourcing, geared towards developing long-term relationships with a sole supplier. They argue that this development is more important than the possible consequences of ICT, which therefore leads to use of more hierarchical coordination instead of markets. Hess and Kemerer (1994) studied five electronic coordination mechanisms in the home mortgage industry and found that the ones that survived in the long term were electronic hierarchies, not electronic markets, again contradicting the Malone, Yates and Benjamin-hypothesis. They suggest that the failed marketplaces may not have aligned the incentives in the marketplace properly, which leads to reduced adoption and eventually failure. Other relevant factors in this respect are the relative market power of buyers and suppliers, as well as which party owns the market.

Other researchers have refined the original theoretical arguments and arrived at similar conclusions regarding the importance of market participants' sourcing strategy. Clemons, Reddi and Row (1993) pointed to the neglected variable of transaction risk and posed the "move to the middle hypothesis". This said that although there will be an increase in outsourcing of activities caused by ICT (which was validated by Brynjolfsson, Malone, Gurbaxani and Kambil (1994)), this increased outsourcing will be from a relatively small number of suppliers, with which the firm has long-term cooperative relationships. This network-like structure is chosen in order to reduce the risks of opportunistic behavior and the loss of critical resources, while also providing higher incentives for investments in IT, organizational adaptations and learning processes. Bakos and Brynjolfsson (1993) arrived at a similar conclusion reasoning from the economic literature on incomplete contracts, when they argued that ICT increases the importance of "non-contractibles" such as quality, innovation, responsiveness and information sharing in buyer-supplier relationships. Both these articles show that there are more factors than asset specificity and complexity of product description at play when determining the choice of coordination mechanism.

Steinfield, Kraut and Plummer (1995) highlighted the importance of the openness of the technical infrastructure and the locus of control of the infrastructure. Particularly the locus-of-control variable influences the resulting coordination structure, because unless the infrastructure is controlled by a neutral third party, entry barriers and lock-in are likely to arise (not unlike the results found by Hess and Kemerer (1994)). This would result again in network-like configurations. Holland and Lockett (1997) took a slightly different approach when they proposed the "mixed-mode hypothesis". They argue that, instead of a single preferred coordination mode, firms use combinations of market and hierarchy-type relationships with their suppliers. Furthermore, instead of causing a shift one way or the other, ICT allows firms to maintain such relationships simultaneously. The specific organizational context will determine which type of electronic relationship will arise, although they do not offer any predictions as to how the organizational context will determine electronic coordination mechanism choice.

Other than the proposed shift from electronic hierarchies to electronic markets, Malone, Yates and Benjamin (1987) also identified an electronic brokerage effect. Electronic markets can connect many different buyers and suppliers through a central database, which theoretically could reduce the need for brokers and other intermediaries. This 'disintermediation hypothesis' has often been repeated in the popular press (Champy 1999) as well as the academic literature (Benjamin and Wigand, 1995). However, the work of Steinfield and colleagues shows that empirical evidence does not support such disintermediation (Sarkar, Butler and Steinfield, 1995, 1998; Steinfield, Chan and Kraut, 2000). They give two reasons for this: the first is that the transaction costs for intermediaries also drop because of ICT and this reduction may offset the reduction in transaction costs of a direct buyer-supplier link. The second reason is that an exchange process consists of many more phases than just brokering -the matching buyers and suppliers- (Kambil and van Heck, 1998; Bakos, 1998) and some of these additional functions are not easy to replicate without using an intermediary. For example, how do electronic markets deal with processes such as the legitimization of transactions and the resolution of disputes between buyer and seller? (Kambil and van Heck, 1998) Although in principle the trading parties themselves could fulfill these roles, it is more likely that an intermediary will do that. Having an external party that is perceived as independent by the trading parties will increase the trust that they have in the effective functioning of those processes, thus making markets more viable. As the cost of intermediation drops because of ICT, Steinfield and colleagues predict that there will actually be more intermediaries, as now specialized intermediation for certain phases of the exchange process becomes feasible (Sarkar, Butler and Steinfield, 1995, 1998). Vervest and Dunn (2000) note that the increasing importance of customer information gives rise to new parties skilled in infomediation. Such infomediaries focus on collecting customer information from various parties and organizing it for other businesses to use to deliver customer value.

Bailey and Bakos (1997) and Bakos (1998) arrived at similar conclusions regarding re-intermedation and new roles for intermediaries, using several case studies of successful electronic markets as did Jin and Robey (1999), who drew on literature from sociology and marketing to support the re-intermediation case.

2.3 ICT and market processes

A second stream within the electronic markets literature assumes the choice for market-based coordination has been made and subsequently investigates the differences between electronic markets and traditional markets. It has its roots in Bakos (1991), who emphasized the reduced search costs for buyers in an electronic market. The most important implications of this search cost reduction were an improved allocative efficiency as buyers now can find sellers that better match their needs and a reduction in prices paid, due to increased competition between sellers. This ‘reduced price hypothesis’ has found mixed empirical support. Lee (1998) investigated the case of Aucnet, an electronic auction for second-hand cars in Japan and found that prices in the Aucnet auction were significantly higher than the traditional car auctions and offered several explanations for this phenomenon. The most important explanation is that because Aucnet screened out the low-quality cars (i.e. the ‘lemons’, Akerlof (1970)) through their quality rating system, their cars were on average of higher quality than the traditional car auctions. Subsequent analysis (Lee, Westland and Hong, 1999) showed that correcting for the quality difference did decrease the price difference, but did not eliminate it. Thus, other factors have to be taken into account to explain the price difference. One of these is again related to Aucnet’s quality rating system: besides screening out the lemons, the general thoroughness of Aucnet’s car inspection process increased the trust that bidders had in the quality of the cars being auctioned, which leads to higher prices (see also Lee and Clark (1997)). Another factor is that the electronic representation of the cars made it attractive for sellers to sell their cars through Aucnet so they could avoid the high transportation and parking costs of physical auctions. This wider assortment attracted more buyers and this buyer externality leads to higher prices, which in turn again attracts more sellers and so on. A final factor may be that it is the premium that buyers are willing to pay for not having to physically travel to an auction and for having a higher chance of finding a vehicle that best matches their preferences.

Bailey (1998) also found higher prices online when he compared prices for books, CDs and software online and offline, as well as larger price dispersion online. These findings were particularly surprising as these categories are considered to be homogeneous goods, for which the reduced price effects theoretically should be most forceful (Bakos, 1997). A likely explanation for this was the immature state of electronic commerce at the time of data collection (early 1997). Around that time, competition among Internet retailers was not very strong because few retailers were active on the Internet and the average Internet user had an above-average income and therefore may have been less price-sensitive (Bailey, 1998), which would enable retailers to sustain higher prices. Other potential explanations are high search costs on the Internet due to information overload and the possibility of price discrimination by retailers.

In a follow-up study on books and CDs, Brynjolfsson and Smith (2000) significantly improved Bailey’s data collection methodology in order to arrive at a more accurate price comparison. They do find the predicted lower prices on the

Internet (8-15% difference) and also much smaller price adjustments by Internet retailers, both of which are indications of a more efficiently functioning market. However, they still replicate Bailey's (1998) finding of substantial price dispersion online, even larger price dispersion online than among conventional retailers, which again runs counter to the hypothesis of an efficient market (in the case of homogeneous goods). They note that models of search costs or asymmetric information cannot explain this finding and suggest that heterogeneity among retailers, particularly on issues related to trust and branding, could account for the observed price dispersion (Brynjolfsson and Smith, 2000). Other possible explanations are price discrimination (Clemons, Hann and Hitt, 2000), switching costs (Chen and Hitt, 2000) and convenience and awareness (Smith, Bailey and Brynjolfsson, 1999).

Degeratu, Rangaswamy and Wu (2000) took a different approach when they compared shopping behavior in a traditional supermarket with shopping behavior at Peapod, an online supermarket. They distinguished four categories of search attributes of a product: brand name, price, sensory attributes (product attributes that can be determined through the senses), and non-sensory attributes (product attributes that can be described accurately in words). Focusing on consumer choice behavior and using information integration theory, they found that sensory attributes have lower impact on choices online, whereas non-sensory attributes have higher impact. Brand name also has a higher impact on online choice, but only if there is less attribute information available online than offline. With regards to price sensitivity of consumers, they distinguish between two effects: that of the price discount itself and that of the product being featured or not (a reasonable, but not perfect indicator of a good deal). Online consumers are more sensitive to price discounts when choosing a brand. Traditional supermarket shoppers are much more affected by the product being featured or not. The combined effect of price discount and featuring is smaller for online consumers, which they interpret as online consumers being less price-sensitive overall than offline consumers.

Lynch and Ariely (2000) also investigated the price-sensitivity of online consumers in relation to the search process. In an experimental environment of two competing online wine stores, they manipulated the search costs for price information and for quality information, as well as the ease of cross-store comparison. Easier cross-store comparison increased price-sensitivity (but only if both stores carried the wine that was searched for), but the search costs for price information had no consistent effect. They also found that a lower cost of obtaining quality information led to a decrease in price-sensitivity. Although the relationship between price-sensitivity and the magnitude of the search costs is dependent on the product being sold, their results do suggest that all three types of search costs need to be taken into account, as there is a tradeoff between them. More generally, this implies that comparison-shopping (as enabled by software agents or other intermediaries) does not inevitably lead to an all-out price war as predicted by some (Sinha 2000) when the quality information of differentiated products is readily available.

2.4 New electronic market institutions

The third stream of the electronic markets literature adopts a more institutional perspective, looking at the new market institutions ICT enables and investigating factors that drive or hinder their adoption. Kambil and van Heck (1998) analyzed the success and failure of four ICT-based new trading mechanisms in the Dutch flower auctions. Using a detailed model of exchange processes, they highlighted the intended and unintended changes that occurred and how the key stakeholders (growers, buyers and the auction intermediary) perceived these changes. Their analysis suggests that no key stakeholder must be worse off in the electronic auction if the new market institution is to succeed. They also note that a change in market ownership or new sources of competitive pressure can be a catalyst for creation and adoption of new market institutions.

Clemons and Weber (1996, 1998) have highlighted the potential of ICT to not just automate existing markets, but also to devise new electronic trading systems that can improve the quality of the market. Electronic trading systems can have lower transaction costs and despite the liquidity advantages of established markets, it is possible for such new market institutions to attract a healthy amount of trading volume (Clemons and Weber, 1996). Other than cost advantages, new ICT-enabled trading mechanisms also offer the opportunity to solve shortcomings in traditional markets. A prime example is the Optimark system, which allows more effective trading of large block orders (Clemons and Weber, 1998) as well as an improved way of dealing with traders' preferences (Teich, Wallenius and Wallenius, 1999). Combinatorial auctions (Rothkopf, Pekec and Harstad, 1998), in which bidders can bid on combinations of goods, and the multidimensional

auctions (Koppius, 1998; Bichler 2000) mentioned earlier both represent other innovative new market mechanisms that become more feasible as ICT reduces the costs of computation and information processing that these auctions require.
On a more general level, Kambil, Nunes and Wilson (1999) argue that ICT enables the creation of all-in-one marketplaces that combine multiple trading mechanisms. This allows stakeholders to select dynamically the trading mechanism that best suits their needs in that particular situation, instead of relying on one single way of trading.

Although new electronic markets may objectively provide benefits to stakeholders, the social relationships among stakeholders underlying the traditional market may affect the subjective perception of those potential benefits, which in turn can affect adoption. For instance, traders may not see the need for efficient communication if they have a strong social relationship with other traders (Pisanias and Willcocks, 1999).
Grewal, Comer and Mehta (2001) further investigated the antecedents of participation in electronic markets. They distinguish between three states of participation depending on a firm's level of activity in the electronic market: exploration, expert and passive state. They find that learning ability, legitimacy motives, efficiency motives and IT capabilities are determinants of a firm's state of participation in the electronic market. Higher ability of a firm to learn, more perceived need of the firm to be seen as technologically innovative (legitimacy motives), more focus on achieving efficiency and higher IT capabilities all improve the chance that a firm will be active in the electronic market (either exploratory or as expert). In particular, efficiency motives and IT capabilities are key factors for a firm to attain the expert state.

Several of the findings mentioned in this and the previous paragraphs are echoed by Choudhury, Hartzel and Konsynski (1998) in their study of an electronic market in the aircraft parts industry. They find that buyers do indeed use the electronic market differently depending on the actual nature of the purchase and they also point to the continuing role for intermediaries, particularly for verification purposes. With regards to the nature of competition, they find that because the electronic market in their study only gave product information but not price information, this leads to more effective matching of supply and demand without creating price wars. This implies that the scope of the market, i.e. the phases in a transaction it supports (e.g. search only or also support for valuation processes), is a relevant variable for the analysis of electronic markets.

2.5 Summary

The field of electronic markets is slowly maturing: whereas the first published studies were largely conceptual and agenda-setting in nature, now empirical studies are becoming more common. Particularly the proliferation of electronic markets and auctions on the Internet makes access to empirical data much easier. A common thread through these empirical studies so far is the complexity of the phenomenon: most studies identify new determinants of market processes, outcome, performance and success or show that context factors qualify existing relationships. This implies that not only further empirical studies are necessary to identify more such factors, but also that theorizing becomes necessary (Weick, 1995) to link these factors together and further mature the field. That is what is attempted in chapter 6 in order to provide an answer to the overall research question.

CHAPTER 3 : PRODUCT QUALITY INFORMATION IN ELECTRONIC AUCTIONS[3]

3.1 Introduction

The literature on ICT and market processes reviewed in section 2.3 has focused mainly on the presumed lower search costs of electronic markets. However, there are several more aspects on which traditional markets and electronic markets differ, based on the nature of the technology used for the electronic market. As traders in a market are continuously exchanging information about products, prices and other aspects of the transaction, one relevant aspect is how much information and what types of information the communication channel can carry. For instance, face-to-face communication allows for much richer communication than a simple email. This can have consequences for how well a seller can communicate information about the quality of his products.

This chapter shows how a change in ICT resulted in reduced product quality information available to traders and the consequences this had for the prices of goods in a market. The empirical setting is a large Dutch flower auction that introduced a new ICT-based auction form called screen auctioning. In screen auctioning, flowers are not shown physically anymore to the buyers, who are shown a generic picture instead. Discussions with flower auction employees revealed that in screen auctioning some important cues for product quality (such as the stiffness of the flower stem and flower color) were not available to the bidders, who therefore had less product quality information available to base their bid on.

This study uses a multiple regression model to compare flower prices before and after the introduction of screen auctioning. The results indicate that prices dropped significantly, particularly for more expensive flowers. The next paragraph will describe the theoretical background of product quality information in electronic markets. Paragraph 3 describes the empirical setting of the Dutch flower industry and its auction system as well as a process-stakeholder analysis of the screen auctioning initiative. The fourth paragraph provides the data, model and

[3] This chapter is largely based on Koppius, van Heck and Wolters (1998)

methodology of the study. Paragraph 5 describes the results of the statistical analysis, which are discussed in paragraph 6, and paragraph 7 concludes.

3.2 Theoretical background

The fact that product quality information is important for the way markets function is not a new point. In his seminal article on the market for lemons, Akerlof (1970) showed that unless accurate product quality information is available to buyers before they make their purchase, the low quality products will eventually drive out the high quality product. If the high quality sellers have no way of signaling this quality to potential buyers, buyers will not be willing to pay the premium for this unobserved higher quality. This results in only the low quality sellers remaining profitable. Subsequent research in economic theory has focused mainly on the impact on market performance of varying degrees of signaling accuracy, but *how* to signal product quality accurately is less well investigated. And while advertising research has investigated this particular question intensively, i.e. which types of advertisements generate more consumer confidence in product quality (Vakratsas and Ambler, 1999), it remains unclear how much of these results translate to an online environment (Gallagher, Foster and Parsons, 2001).

There are three empirical studies in which information about product quality plays a central role in comparing traditional and electronic market: Bailey, Peterson and Brorsen's (1991) study of video cattle auctions, Lee's (1998) Aucnet study and Degeratu, Rangaswamy and Wu's (2000) study of traditional and online shopping behavior at grocery stores (see also paragraph 2.3). Bailey, Peterson and Brorsen (1991) compared satellite video cattle auctions with regional market prices. Prices for both the regional and video auctions were adjusted for quality differences, transportation costs, commissions, and days to delivery and they find that net prices paid by buyers and received by sellers in video auctions exceeded the prices for the three major regional auction markets. Although they offer no explanation for this finding, presumably the different way the buyer ascertains cattle quality over video compared to traditional market is a likely explanation.
Lee (1998) pointed to the importance of product representation in combination with Aucnet's quality rating system as an explanation for the higher prices paid in the electronic auction (although lower transportation costs played a role as well). Aucnet attempted to utilize the electronic communication channel to the fullest by

exhaustively showing and describing the car to potential bidders. This increase in the richness of the actual communication did decrease bidder's quality uncertainty, resulting in higher prices. Degeratu, Rangaswamy and Wu (2000) analyze the decision process of a consumer trying to evaluate a product and they distinguish four categories of search attributes, namely brand name, price, sensory attributes (such as touch, smell and sound) and non-sensory attributes, which are product quality attributes that can be conveyed reasonably well through words (such as nutritional information). They show that the differences in the four categories can explain the differences they observe between shopping in an online supermarket compared to a traditional supermarket. In short, these three studies highlight that product quality information is important for the way markets function, as these electronic markets communicate different product information and product information differently.

Specific for the role of product information in auctions, independent private value auctions and common value auctions have to be distinguished (McAfee and McMillan, 1987). In an independent private value auction, each bidder has his private valuation of the object for sale, which is assumed to be independent of the valuation that other bidders have for the same object. An example is the auctioning of a painting intended for personal use (not resale): each bidder will bid purely based on his personal tastes of the painting[4]. In a common value auction, the object has the same value to all bidders, but bidders differ in their estimate of this value. An example is the auctioning of oil drilling rights, where the amount of oil in the tracts remains the same regardless of who wins. Therefore, it is worth the same to each bidder (assuming identical technology among bidders) and the only difference is how accurately each bidder estimates this common value. Milgrom and Weber (1982) showed that for auctions that include a common value component, revealing accurate information about the product being auctioned will increase the winning bid.

[4] Note however that even in this case, the independence of the valuation is doubtful (Smith, 1989).

Figure 3.1 Auction hall

3.3 The screen auctioning initiative

The Netherlands is the world's leading producer and distributor of cut flowers. The world’s two biggest flower auctions are in Aalsmeer (Flower Auction Aalsmeer) and Naaldwijk (FloraHolland); every day on average 30 million flowers - originating not only from the Netherlands but also from countries such as Israel, Kenya and Zimbabwe - are traded in 100,000 transactions. In total, there are seven Dutch flower auctions, namely in the villages of Aalsmeer, Naaldwijk/Bleiswijk, Rijnsburg, Grubbenvorst, Eelde, Bemmel, and Vleuten. The Dutch flower auctions play a vital role in Holland's leadership of this industry, by providing efficient centers for price discovery and transactions of flowers between buyers and sellers. These auctions traditionally use the 'Dutch auction' as the mechanism for price discovery. They are established as cooperatives by the Dutch growers.

The auction rules of the Dutch flower auctions are described using some empirical data to illustrate its characteristics and results, taken from van Heck and Ribbers

(1998). There are approximately 3500 varieties of cut flowers. These varieties are classified into 120 auction groups, according to the variety, size of the lot, and quality of the flowers. Dutch flower auctions use a clock for price discovery as follows. The computerized auction clock in the room provides the buyers with product characteristics such as stemlength or diameter or number of leaves (dependent on the particular flower type), as well as information on the producer, unit of currency, quality and minimum purchase quantity. The flowers are transported using an automated chain system through the front of the auction room, where there is a person (the 'raiser') who shows the flower to the more than one hundred buyers in the stand. Figure 3.1 illustrates this with a photo of a typical flower auction hall: the flower carts enter on the mid-left, pass underneath the auction clock (upper left corner) where the raiser is and after they are sold exit through the top end to be packaged and shipped. The clock hand starts at a high price determined by the auctioneer, and drops until a buyer stops the clock by pushing a button. The auctioneer asks the buyer by intercom, how many units of the lot he or she will buy. The buyer provides the number of units. The clock is then reset, and the process begins for the remaining flowers, sometimes introducing a new minimum purchase quantity, until all units of the lot are sold. Table 3.1 illustrates the auction process by an example with some actual auction data. The first rows deal with producer 1234 (column 2), who is responsible for transactions 408 to 420 (column 1). On January 4, 1996 this producer delivered roses (product group 52), or more specifically the brown rose 'Leonidas' (product number 10288). He delivered four lots of that type of rose (column 4). These lots had the same type of quality (A1), but were different in length (70, 60, 50, and 80 centimeters respectively) and in amounts of 9, 5, 3, and 12 units respectively. The first lot was auctioned, and buyer 3782 took 1 unit (out of 9) for a price of 93 cents per stem. The rest of the lot was auctioned again, and buyer 1854 bought 2 units for 95 cents. The remainder of the lot (6 units) was auctioned, and buyer 727 bought 3 units for 96 cents. Finally, buyer 42 bought the rest of the lot for 97 cents. The table shows that the price may increase during the auctioning of a lot (see, for example, transactions 408 through 411) or may decrease within a lot (see, for example, transactions 729 through 731). So the price is very volatile, considering different lots of the same producer or different lots of different producers.

Table 3.1: Illustration of flower auction process and data (adapted from Van Heck and Ribbers (1998))

Trans-action nr.	Producer	Product group	Product	Quality	Length in cm.	Total # of units	Stems per unit	Buyer	# units	Price in cts./stem
408	1234	52	10288	A1	70	9	100	3782	1	93
409								1854	2	95
410								727	3	96
411								42	3	97
412	1234	52	10288	A1	60	5	100	727	4	89
413								1824	1	91
414	1234	52	10288	A1	50	3	100	3090	1	67
415								2528	2	68
416	1234	52	10288	A1	80	12	100	3282	4	109
417								4157	1	115
418								134	3	115
419								3462	2	116
420								3042	2	117
727	12	52	11087	A1	80	3	100	2893	2	91
728								752	1	87
729	12	52	11087	A1	70	6	100	727	1	79
730								1768	2	77
731								3004	3	77
732	12	52	11087	A1	60	8	100	3219	1	56
733								2669	3	56
734								727	4	54
735	12	52	11087	A1	50	3	100	727	3	46

Buyers must be physically present in the auction room. In practice, it turns out that the Dutch flower auction is an extremely time-efficient auction mechanism: it can handle a transaction every four seconds. It also reduces the amount of time that growers must spend on price discovery and bidding; hence they can focus on production.

The auction provides a central location for the meeting of buyers, creating efficient quality control and efficient handling of the logistics of product redistribution between the thousands of growers and buyers involved. This auction has "backtracking" possibilities: though the price movements are decreasing per sub-lot, the price can be multidirectional (up or down) within the whole lot. Buyers can withdraw their willingness to buy: they can indicate to the auctioneer fewer or more units then they originally intended to at the time they pushed the button.

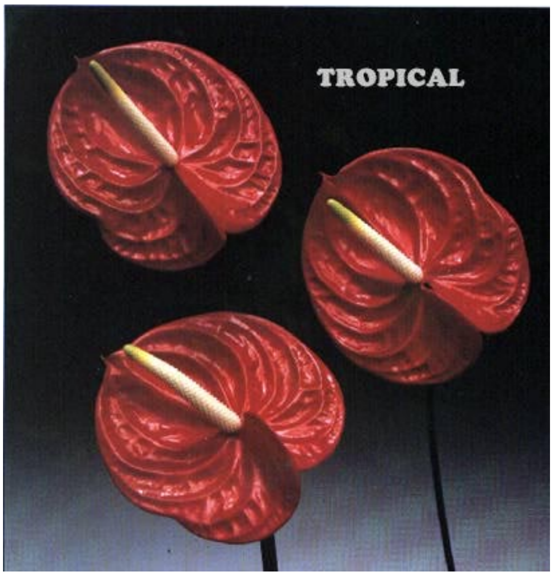

Figure 3.2 Anthurium Tropical

Thus, during the auctioning of the lot, buyers produce information on the value of the lot; this information is available to all buyers.

As mentioned previously, all flowers that are put up for auction pass through the auction hall in order to be shown to the buyers just before the bidding starts. Given the large daily turnover and the very fast auctioning process, this process entails tremendous logistical complexities for the auction and any malfunction in the automated chain system causes significant delays in the auction process. To alleviate such problems, the flower auction introduced screen auctioning for the flower type Anthurium in February 1996 (fig 3.2 shows a picture of most common Anthurium variety, the Tropical). In screen auctioning, the buyers are still present in the auction hall, but they are no longer shown the flowers as in the traditional auction method. Instead, the flowers remain in the warehouse and buyers are shown a picture for that type of flower. This is a generic picture, irrespective of lot differences within the same type, but they still see the specific product characteristics of that particular lot below the auction clock (see fig. 3.3 for an illustration).

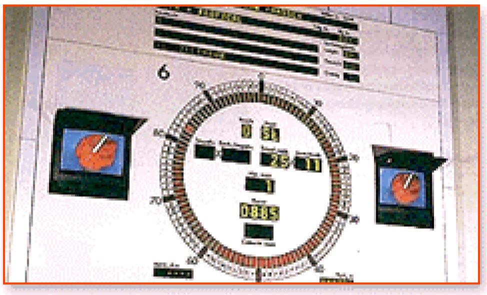

Figure 3.1 Screen auctioning

When screen auctioning was introduced, two other aspects of the trading process changed as well. The time of auctioning Anthuriums was rescheduled to an earlier time (6am) and screen auctioning was introduced as a third clock in one of the auction halls, so now three concurrent auctions take place in that hall. In February 1998, screen auctioning was expanded to cover the flower type Gerbera as well. The research in this article deals with Anthuriums only.

Kambil and Van Heck (1998) specify a generalizable model of exchange processes and develop a process-stakeholder analysis framework to evaluate alternative market designs. They identify five basic trade processes: search, valuation, logistics, payments and settlements, and authentication. The basic trade processes are distinct processes required in all transactions of goods and services. The trade context processes facilitate and enable or reduce the costs or “frictions” in the basic processes. The five trade context processes are communications and computing, product representation, legitimization, influence, and dispute resolution.
Table 3.2 presents the results of the analysis of screen auctioning with the help of the process-stakeholder framework. For each of the stakeholders, the actual changes or expectations related to screen auctioning are described. As can be seen, sellers, intermediary and buyers differed in their expectations of the effects of screen auctioning, particularly the expectations about the accuracy of product representation and its consequences for price.

Table 3.2 Process stakeholder analysis of screen auctioning

Exchange Process	Growers	Auction	Buyers
Search	No change	No change	No change
Valuation	*Expected*: possible higher prices because of earlier auctioning time	*Expected*: no expectation with regard to impact on prices	*Expected*: no expectation with regard to impact on prices
Logistics	*Expected*: more trading capacity at auction hall	*Expected*: Auction hall logistics would be eliminated allowing for cheaper and more frequent transactions and new space for clocks	*Expected*: faster delivery of flowers due to by-passing auction hall
Payments and Settlements	No change	No change	No change
Authentication	No change	No change in quality grading process	No change
Communication and Computing	No change	Major change: digital representation of product with standard image next to clock	No change
Product Representation	No change	*Expected*: digital representation of each lot; representation would represent the actual flower accurately enough to have no effect on prices	*Expected*: digital representation of each lot; representation could lead to less information on quality of flowers
Legitimization	No change	No change	No change
Influence	No change	No change	No change
Dispute Resolution	No change	No change	No change
Net Benefits	Positive	Positive	Neutral

3.4 Data and methodology

To investigate quantitatively the impact of screen auctioning, a regression model is constructed that predicts the price of an Anthurium before and after the introduction of screen auctioning. This model is tested on the auction transaction database using transactions from January 1995 until December 1997 (screen auctioning was introduced on Feb. 13th, 1996). In this database, for every transaction various data are kept, including data related to the seller, the buyer, the product (flower type, quality, stemlength, diameter and other flower characteristics (depending on the particular flower type)), and the transaction itself (price, quantity, date).

Discussions with flower auction employees revealed several factors that influence the Anthurium price that were use as control variables in the model. For Anthuriums, diameter of the flower (DIAM) is an important descriptive characteristic. The day of the week (WKDAY) influences price as well because different days of the week have structurally different supply and demand characteristics. For instance, demand tends to be highest at the beginning and end of the week. Similarly, the trade of Anthuriums (and flowers in general) is highly seasonally dependent. Therefore, this seasonal effect in the regression is corrected for by including the average Anthurium price at all other flower auctions in Holland (VBN) as an extra variable. The quantity of the transaction (QUANT) is taken into account because bidders are expected to bid differently for large or small quantities. For each of the 9 flower subtypes in the database, a dummy variable $FLWTYPE_i$ is added to account for the different prices that different subtypes fetch. The effect of screen auctioning in the model is a dummy variable SCRAUC: 0 (without screen auctioning) for transactions before February 13, 1996; or 1 (with screen auctioning) for transactions on or after February 13, 1996. This results in the following model:

$$PRICE = \alpha + \beta_1 DIAM + \beta_2 WKDAY + \beta_3 VBN + \beta_4 QUANT + \beta_{5,i} FLWTYPE_i + \beta_6 SCRAUC + \varepsilon. \qquad \text{(Eq. 3.1)}$$

Under screen auctioning, buyers lack several product characteristics compared to the physical representation: the color and shape of the flower, differences between flower leaves, signs of possible flower diseases and the stiffness of the flower. In particular the absence of the stiffness cue is problematic, because stiffness is an important indicator of flower freshness, which in turn is an important determinant of a buyer's willingness-to-pay for that flower. Given the common value aspects of the auction (because the flowers are purchased for resale, not for personal consumption), this lack of freshness information will lead buyers to expect a lower quality on average for fear of purchasing a 'lemon' (Akerlof 1970, Milgrom and Weber 1982). This leads to the following main hypothesis:

Hypothesis 3.1: $\beta_6<0$, i.e. screen auctioning will lead to lower prices.

The dataset contained the nine most traded types of Anthuriums. Although the flower auction had a quality grading system in place, approximately 98% of all Anthurium flowers traded were of the highest quality (quality grade A1), so the analysis focused only on this quality grade and removed quality grades A2, B1 and B2 from the analysis. The remaining database consisted of 372,856 transactions (cases with missing values excluded). One data transformation was used, namely the natural log of the quantity. Quantity was very skewed to the right and taking the natural log restores the validity of the normality assumption necessary for regression. The model was estimated using OLS regression. Although there is a time element present, regression analysis was used instead of time series analysis, because running a time series analysis would require aggregation of the data to at least the daily level. This would throw away much of the level of detail that is present at the individual transaction level. This does mean however that there is significant autocorrelation present in the data, as evidenced by the Durbin-Watson statistic of 0.491. In principle, this results in a loss of power for the test, but given the very large number of cases, this power loss is expected to be unimportant (Baroudi and Orlikowski, 1989; Tabachnick and Fidell, 2001).

3.5 Results

Descriptives can be found in Table 3.3, cross-correlations in Table 3.4 (dummy variables excluded) and the results of the regression model in Table 3.5. The overall model had an adjusted R^2 of 0.577, so the model explains 57.7% of the variance in Anthurium prices. The main result can be found in Table 3.5, where the coefficient for the SCRAUC dummy is significantly less than zero, thus yielding support for the main hypothesis.

Table 3.3 Descriptive statistics

	N	Minimum	Maximum	Mean	Std. Deviation
DIAM	372856	1	99	11.86	2.54
QUANT	376130	5	2304	94.54	132.87
VBN	376130	80.40	239.90	143.0326	42.8683
PRICE	376130	30.00	600.00	151.8054	77.9451

Table 3.4 Cross-correlations

	DIAM	QUANT	VBN	PRICE
DIAM	1.000			
QUANT	-.073**	1.000		
VBN	.024**	-.055**	1.000	
PRICE	.397**	-.157**	.596**	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

Table 3.5: Regression model coefficients

	Unstandardized Coefficients		Standardized Coefficients		
Variables	B	Std. Error	Beta	t	Sig.
Constant	-135.513	.534		-253.888	.000
DIAM	10.666	.034	.347	317.323	.000
QUANT	-2.91E-02	.001	-.050	-44.866	.000
VBN	1.076	.002	.592	553.179	.000
ART_381	23.309	.310	.085	75.180	.000
ART_1430	30.280	.371	.092	81.560	.000
ART_1903	20.792	.272	.090	76.514	.000
ART_2362	60.456	.383	.176	157.974	.000
ART_2837	10.525	.275	.044	38.292	.000
ART_5578	16.095	.973	.018	16.541	.000
ART_7445	54.056	.315	.196	171.337	.000
ART_7759	44.164	.435	.112	101.573	.000
TUESDAY	-5.066	.231	-.028	-21.911	.000
WEDNESDAY	-10.377	.249	-.052	-41.714	.000
THURSDAY	-4.127	.353	-.014	-11.676	.000
FRIDAY	-3.520	.239	-.019	-14.732	.000
SCRAUC	-5.942	.174	-.037	-34.182	.000

3.6 Discussion

The results indicate that the main hypothesis is supported. This implies that the reduced product quality information available to bidders led them to bid lower on average. The electronic product representation lacked cues such as color and stiffness of the stem that bidders use (among other factors) to determine product quality and subsequently their willingness-to-pay. In particular, stem stiffness is an important indicator of flower freshness and thus very relevant to bidder's decisions. Since these cues were lacking in screen auctioning, bidders faced greater uncertainty over product quality. They accounted for this increased product quality uncertainty by lowering their bids.

However, there are some other factors, which are not in the model that may also influence bidding behavior and price setting. The auction is modeled as a common value auction, but it is possible that there are private value elements. For instance, different buyers may face different demand from their customers. Most buyers are agents who buy ‘on order’, which means that they have to get a certain amount of flowers that day because of pre-orders from their customers. This will most likely cause them to bid higher on average. Similarly there are some speculative buyers in the market that are only likely to bid for flowers if they can get them at a low price. This will most likely cause them to bid lower on average. If different buyers bid structurally different, that would imply that dummy variables for the buyers should be incorporated in the model as well. This extension of the model was considered, and tested on a subset of transactions with only the 20 largest buyers, who accounted for almost 28% of all transactions. Introduction of buyer dummy variables in this case only marginally raised the adjusted R^2, but more importantly, it did not significantly alter any of the coefficients of the variables compared to the original model without the buyer dummy variables. So in the interest of parsimony, the buyer variable was left out of the model. Similarly, one could argue that different sellers (i.e. the growers) might receive different prices on average for their flowers because of their reputation for producing high (low) quality flowers. An extended model with a subset of dummy variables for the larger growers was tested and it yielded similar results: a marginal increase in adjusted R^2 without any significant changes in the other coefficients compared to the original model. Therefore, although there is a small, but significant reputation effect, it was left out of the model.

The discussion above is about modeling decisions that could have explained an effect attributed to screen auctioning. However, there are also rival explanations that could not be modeled, yet may account for the screen auctioning effect. When screen auctioning was introduced, three aspects changed: the product representation, the introduction of a third auction clock in the auction hall and the earlier auctioning time. The latter two changes are discussed below, as they could represent rival explanations.

When the third clock was introduced, several buyers complained about how difficult it was to keep track of three clocks at the same time. Most buyers at the flower auction buy ‘on order’. Hence, they have a contractual obligation to deliver the flowers to their customer and presumably they do not want to risk *not* getting the flowers their customers ordered. This implies that the increased cognitive complexity of the bidding process and the accompanying increase in uncertainty (in this case uncertainty over being able to obtain the flowers or not, not uncertainty over product quality) would lead to buyers bidding sooner and hence their paying higher prices. With respect to the influence of an earlier auctioning time on bidding behavior[5], there is no empirical evidence but flower auctioneers said that in their experience, earlier auctioning times lead to higher prices. As these two potentially confounding factors both would have led to higher prices, the conclusion is that the lesser product quality information available in screen auctioning is the most likely explanation for the observed drop in prices.

3.7 Conclusions

This chapter presents the results of empirical research on the price impact of a new method of auctioning, using transaction data obtained at a large Dutch flower auction. In February 1996, this auction introduced screen auctioning to separate the logistical processes from the price discovery process, thus decreasing the costs and complexity of the total distribution process. In screen auctioning, the buyers are still present in the auction hall, but they are no longer shown the actual flowers. Instead, a generic picture is displayed on a monitor next to the auction clock. This meant that several cues for product quality such as the color and shape of the flower, differences between flower leaves, signs of possible flower diseases and the stiffness of the flower stem were now absent.

The conclusion is that less product quality information leads to a reduction in prices in electronic market, as seen in a significant price drop of nearly 6 cents (Table 3.5) after the introduction of screen auctioning. This represents about 2.1% of the average flower price. Despite this price reduction, the flower auction organization still considered screen auctioning a success (although not as big a success as originally expected). As the auction receives a percentage of the value of each transaction as fee, lower prices did mean a loss of transaction fees, but according to auction personnel, this loss was negligible compared to the avoided cost of dealing with the increased logistical complexities.

[5] Note that this is a different question than the 'declining price anomaly' observed in other multi-unit auctions (Ashenfelter, 1989; McAfee and Vincent. 1993). This anomaly will occur regardless of whether the exact same lots are auctioned at 6am (as in the screen auction schedule) or at 9am (as in the original auction schedule).

Screen auctioning can be seen as an intermediate step towards a full electronic market, since they both involve a shift from live product representation to image-based product representation. The difference is that in screen auctioning, contrary to an electronic market, the buyers still assemble physically in the auction hall. So although screen auctioning is not a pure electronic market, the results indicate that a decrease in price level should be expected when goods are traded and sold electronically, unless ways are found to counter the information-quality problem. For example, one factor that may have aggravated the negative results of screen auctioning is the lack of a good quality rating system. The auction operates a quality system with four categories where growers self-report the quality of the flowers. Partly because of opportunism, partly because of the few categories, 98% of the flowers are in the highest quality category. This effectively renders the quality rating system useless. Note that this is also in accordance with the results in Lee (1998), which identify Aucnet's quality rating system as a key success factor of the auction. A good quality assurance process is an important key to a successful electronic market.

CHAPTER 4 : MARKET STATE INFORMATION IN ELECTRONIC AUCTIONS

4.1 Introduction

As mentioned in the previous chapter, a move from a traditional auction to an electronic auction entails several changes. One such change is in the product representation, in other words how product quality information is made available through ICT, as investigated in chapter 3. This chapter deals with a second change, namely the fact that buyers no longer have to physically gather in one place to bid as in a traditional auction. This physical gathering can be very cumbersome and leads to high transaction costs because the buyers have to incur extra time and travel costs to get to the auction hall.

In practice, auction houses use several strategies to offset these high transaction costs. One strategy is bundling: only conduct an auction if you have a bundle of items up for auction that are likely to attract a similar audience. That way, potential buyers face less transaction costs than in the situation where each item would be auctioned as soon as it became available to the auctioneer. Another strategy is to allow mail-in bids or phone bids: bidders can privately announce their highest bid (i.e. their willingness-to-pay) to the auctioneer before the auction, who then conducts the auction, as if the bidder were present in the room. In the case of phone bids, bidders can also stay on the phone with the auction hall during the auction. That way they can bid just as if they were physically there, except for the fact that they cannot see the actual product and the other bidders. Both mail-in and phone bidding reduce the transaction costs of the auction for such bidders.

Essentially, electronic bidding through new ICT forms such as the Web and email are new variants on the phone bidding principle. However, an added advantage of electronic bidding is that it is cheaper than phone bidding and perhaps more importantly, the information disadvantage of phone bidding can be countered to some extent through electronic product representation, although the previous chapter showed that nullifying this information disadvantage is by no means easy. One aspect of phone, mail or electronic bidders remains though: they do have an information disadvantage compared to the bidders in the auction hall. For instance, they cannot see how many bidders there are, they cannot see if specific bidders are present or not and they cannot hear the level of excitement or ‘buzz’ (Coval and Shumway, 2000) of the auction. These types of information belong to what more generally can be called market state information, which can be defined as public, non-transaction signals that influence trader behavior (adapted from Coval and Shumway (2000)). As such information can have a significant impact on market processes (Coval and Shumway, 2000; Engelbrecht-Wiggans, 2001), the changes in market state information available to traders in electronic markets compared to traditional markets are a subject worthy of investigation.

This chapter will investigate an ICT initiative called KOA (‘Kopen Op Afstand’, which means ‘Buying From A Distance’) at the same Dutch flower auction at which the study in chapter 3 was conducted. In this case, bidders had the option to bid from their offices, using special software and an ISDN linkup to the computer in the auction hall. These electronic bidders, or KOA-bidders, participated in the exact same auctions that the bidders in the auction hall itself were bidding on, so electronic bidders and auction hall bidders were competing against each other. This allows a direct comparison between electronic bidding behavior and traditional auction hall bidding behavior. The focus is on the same type of flower that was used to study screen auctioning, the Anthurium. Because the KOA initiative occurred about a year after the introduction of screen auctioning, the only change for KOA-buyers was a reduction in transaction costs and market state information as the change in product quality information had already taken place (see also the discussion in section 3.7). This is an important methodological point, because previous studies of electronic markets could not distinguish between these two effects, since the effect of reduced product quality information occurred at the same time as the effect of lower transaction costs and reduced market state information.

The next paragraph describes the theoretical background regarding the differences between traditional and electronic bidding behavior caused by lower transaction costs. Paragraph 3 describes the KOA initiative (background on the Dutch flower industry and general information about the flower auction investigated here can be found in the previous chapter). Paragraph 4 provides the data, model and methodology. Paragraph 5 describes the results of the statistical analysis, which are discussed in paragraph 6 and paragraph 7 concludes.

4.2 Theoretical background

One of the main arguments for the reduced price hypothesis (Bakos, 1991, 1997) in electronic markets is the lower transaction costs that buyers face, particularly lower search costs. Buyers in electronic markets can much more easily search for price information among competing buyers in the same market or in other markets. This intensifies price competition, resulting in erosion of seller's margins and therefore lower prices for buyers. Another fairly straightforward implication of lower transaction costs is that the average transaction size for electronic bidders will be smaller than for traditional bidders, as there are less gains to be had from conducting only a few large transactions as opposed to a set of small transactions.

This in turn has implications for the variety of products that buyers buy and the amount of suppliers that they deal with. Because transaction costs are lower, there are fewer costs associated with purchasing new types of products or dealing with new suppliers. Although the risk associated with trying out something new (either a product or a supplier) is just as large in an electronic market as in a traditional market, the cost of trying out something new is lower. Electronic bidders are therefore more likely to purchase a wider variety of products and deal with a larger set of suppliers than traditional bidders (Lynch and Ariely, 2000).

There is an important caveat to the analysis above however: it rests on the assumption that there are no switching costs from market to market for bidders (Grover and Ramanlal, 1999). If switching costs arise, buyers risk being locked into a certain market because although there may be benefits from obtaining a lower price or better product in a different market, these benefits may be outweighed by the costs of switching to that market. Switching costs can arise for a number of reasons, many of which occur on the Internet nowadays. Market owners can erect entry barriers, such as certification processes for potential new entrants. There may be technological switching costs such as having to buy and install new software to participate in a new market. A type of cognitive switching costs can arise if a new market uses a different auction mechanism. As ICT allows more sophisticated auction mechanisms to be used, it can take quite some time before bidders are accustomed to them and know which bidding strategies to use and not to use. Finally, sellers or market owners may follow a personalization strategy based on the buyer's profile, which tailors the market and website specifically to that buyer's needs. As building up an accurate profile takes time and effort, this can keep buyers locked in a certain market.

4.3 The Buying-At-A-Distance initiative

The Buying-At-A-Distance initiative (further to be referred to by its Dutch acronym, KOA, 'Kopen Op Afstand') started as a pilot-project with electronic bidding. Initially, it was offered to a few large buyers, who were expected to be the most likely early adopters for two reasons. One reason was that the KOA system required a significant investment in hardware and software: a dedicated computer, a double ISDN line for communication with the auction hall (one line for the connection with the auction computer, one for verbal communication with the auctioneer) as well as monthly fees of approx. € 400 to use the system. The other reason was that the auction expected that larger buyers would be able to save on purchasing personnel costs, as the KOA system allowed buyers to efficiently monitor all the 10 auction clocks that run in parallel. Traditionally, large buyers needed to have several buyers present, one or more in each of the four auction halls to be able to do this monitoring efficiently. One of the expectations of the KOA system was that buyers would be able to do with one or two fewer purchasing personnel, which would offset the costs of the system.

In the KOA system, buyers did not see the actual flower (or a generic picture), but otherwise they did see the same information they would see if they were in the auction hall, i.e. information about upcoming auctions, minimum lot size, the supplier and various lot characteristics. They had a picture of the auction clock on their screen that was synchronized with the auction clock in the auction hall. Bidding was done by pressing the space bar.

The KOA system quickly became a success as the benefits became obvious (see Mulder (1999) for more background on the KOA initiative). Interviews with buyers revealed that several of them saved significantly on personnel costs and all buyers were enthusiastic about the fact that they did not need to travel to the auction early in the morning. The most frequently mentioned benefit was the increased market monitoring capabilities that the system offered, both within the auction (switching auction clocks) as across flower auction organizations. Practically all KOA-buyers used the system in conjunction with similar electronic systems from two or three rival flower auction organizations. Often they would follow the same type of flower at three different auctions simultaneously and buy where the current price and quality are most favorable. This implies that the lower search and switching costs are particularly salient to the bidders. It also implies

that despite the varying geographical distances, transportation costs are not sufficiently different across auction sites to be taken into account in bidding decisions about individual transactions. This makes sense, given the fact that most KOA bidders buy from all major auctions each day (either electronically or physically), so the additional transportation costs of an extra transaction are relatively small as long as no extra truck is needed.
The rollout of the system was subsequently expanded to mid-size buyers as well. In late 2001, the KOA system had 118 subscribers and had generated over € 50 million in turnover.

Not all KOA-buyers were alike though: several buyers (particularly the larger ones) had an office on the auction complex itself, in addition to their regular office. These internal buyers could also use the KOA system from those offices. This meant that they had the option to walk through the flower warehouse in the morning and judge the quality of the flowers and then return to their (internal) office to bid through KOA. In those internal offices, they also had access to the security camera system, which enabled them to monitor activity in the auction hall. The external KOA buyers did not have these options as they did not have an office on the auction complex. To account for this informational difference, the model will distinguish between internal and external KOA buyers in the analysis in the next paragraph. Summarizing the differences among the three groups of buyers:

- Internal KOA-buyers vs. auction hall-buyers: internal KOA-buyers have lower search costs and lower switching costs.
- External KOA-buyers vs. auction hall-buyers: external KOA-buyers have lower search costs and lower switching costs, but they have less information about product quality and also less market state information.
- Internal KOA-buyers vs. external KOA-buyers: internal KOA-buyers have more information about product quality and market state.

Table 4.1 presents the results of the analysis of KOA with the help of the process-stakeholder framework (Kambil and van Heck, 1998). For each of the stakeholders the changes and expectations related to KOA are described.

Table 4.1 Process –stakeholder analysis for KOA

Exchange Process	Growers	Auction	Buyers
Search	No change	No change	Online database that is much more transparent and up-to-date. Also, buyers can 'flag' auctions and then be notified when those start
Valuation	*Expected:* no changes	*Expected*: higher prices because KOA would attract new buyers and hence more competition	*Expected*: lower prices through better comparison of auctions
Logistics	Earlier delivery of products for KOA compared to traditional auctions	Earlier delivery of products for KOA compared to traditional auctions	No change
Payments and Settlements	No change	No change	No change
Authentication	No change	No change in quality grading process	No change
Communication and Computing	No change	Double ISDN line to the buyers offices. The auction has to enter the supply data in the KOA database at night.	Double ISDN line to the auction computer
Product Representation	No change	*Expected*: the loss of image information would have no effect on prices	*Expected*: digital representation of each lot; representation could lead to less information on quality of flowers
Legitimization	No change	No change	No change
Influence	No change	No change	No change
Dispute Resolution	No change	No change	No change
Net Benefits	Neutral	Positive	Positive

4.4 Data and methodology

A dataset with the same data format as the one used in chapter 3 was obtained for this study, in this case the years 1997 and 1998. KOA was introduced in early 1997, with a second rollout phase in the summer of 1997. A model similar to the one constructed in paragraph 3.4 for the screen auctioning case, with this model having a dummy KOA to indicate whether or not the buyer was a KOA buyer (KOA=1) or an auction hall buyer.

$$PRICE = \alpha + \beta_1*DIAM + \beta_2*WKDAY + \beta_3*VBN + \beta_4*QUANT + \beta_{5,I}*FLWTYPE_i + \beta_6*KOA + \varepsilon. \qquad \text{(Eq. 4.1)}$$

Based on the theoretical discussion in paragraph 4.2, the following hypothesis will be tested:

Hypothesis 4.1: Because of lower search costs and lower switching costs, KOA-buyers will bid less than hall-buyers, i.e. $\beta_6<0$.

In this hypothesis, the effect of reduced market state information for KOA-buyers is not taken into account. This effect is expected to be much smaller than the effect of reduced search and switching costs and would therefore not show up as a separate factor in the analysis.

Because internal KOA buyers suffer less from the information asymmetry of not being able to see the flower that plagues external KOA buyers, they will discount less for quality uncertainty (analogous to the previous chapter). A second model (Eq. 4.2) was constructed in which the KOA dummy was replaced by two dummies KOAEXT and KOAINT, to indicate if the buyer was an external KOA buyer or an internal KOA buyer. If both dummies were zero, the buyer was an auction hall buyer. So in this analysis there were three groups of buyers.

$$PRICE = \alpha + \beta_1*DIAM + \beta_2*WKDAY + \beta_3*VBN + \beta_4*QUANT + \beta_{5,I}*FLWTYPE_i + \beta_6*KOAINT + \beta_7*KOAEXT + \varepsilon. \qquad \text{(Eq. 4.2)}$$

The following hypotheses will be tested:

Hypothesis 4.2a: Because of lower search costs and lower switching costs, both internal and external KOA buyers will bid less than auction hall buyers, i.e. $\beta_6<0$ and $\beta_7<0$.
Hypothesis 4.2b: Because of more product quality information being available to them, internal KOA buyers will bid more than external KOA buyers, i.e. $\beta_6>\beta_7$.

Again in these hypotheses, the effects of reduced market state information is not taken into account, because it is expected that the effect of product quality information (which is presumably more salient to the buyers' bidding decisions) will be much larger.
Data transformation and methodology were similar to paragraph 3.4

4.5 Results
The two models above were tested on 81,370 transactions for Anthuriums using sequential OLS regression with two blocks of variables. The first block contained all the control variables: VBN-price, diameter, length, quantity and dummies for flowertype and day of the week. The second block contained the variable(s) of interest, KOA in the first model, KOAINT and KOAEXT in the second model.
The reason for choosing this sequential regression approach is a theoretical one. The order in which variables are entered into the regression equation can drastically affect the interpretation of the results for individual independent variables (Tabachnick and Fidell, 2001, p.131-139), which can affect the correct testing of hypothesis. If the goal of this model were to simply construct the best possible model for explaining the price of flowers, a stepwise regression approach could have sufficed. In that case, the individual contributions of independent variables are of less importance than when hypothesis testing is the goal of the model. Therefore, although the model could have been estimated in a single regression step, it is more appropriate to use a two-step approach with the main variable entering after all control variables are entered. This ensures that the added effect is uniquely due to that variable and not captured by the control variables.

Table 4.2 Descriptives KOA model 4.1

	N	Minimum	Maximum	Mean	Std. Deviation
PRICE	81791	30.00	715.00	173.1530	87.7783
VBN	81803	73.60	279.40	142.2774	41.6919
DIAM	81381	5.00	29.00	13.2099	2.7345
QUANT	81803	5.00	2304.00	70.8860	104.4122
Valid N (listwise)	81370				

Table 4.3 Crosscorrelations KOA model 4.1

	PRICE	VBN	DIAM	QUANT	MON	TUE	WED	THU	FRI	KOA
PRICE	1.00									
VBN	.52**	1.00								
DIAM	.53**	.03**	1.00							
QUANT	-.23**	-.04**	-.23**	1.00						
MON	.04**	.00	.02**	.00	1.00					
TUE	.02**	-.02**	.04**	-.01**	-.35**	1.00				
WED	-.06**	-.02**	-.02**	.00	-.31**	-.24**	1.00			
THU	-.04**	.02**	-.04**	.02**	-.17**	-.13**	-.12**	1.00		
FRI	.00	.02**	-.01**	-.01	-.37**	-.29**	-.26**	-.14**	1.00	
KOA	-.05**	.02**	-.04**	.27**	-.01*	.00	.00	.01*	.00	1.00

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.4 Regression coefficients KOA model 4.1

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	-162.887	3.311		-49.198	.000
TUE	-4.555	.458	-.021	-9.948	.000
WED	-7.423	.488	-.032	-15.210	.000
THU	-6.255	.739	-.017	-8.463	.000
FRI	-2.124	.447	-.010	-4.751	.000
DIAM	13.089	.080	.408	162.980	.000
VBN	1.061	.004	.504	271.329	.000
QUANT	-3.739E-02	.002	-.045	-21.850	.000
KOA	-2.795	.360	-.015	-7.754	.000

Table 4.2 contains the descriptives for the first model, table 4.3 its cross-correlations. Table 4.4 shows the regression coefficient of the final model. This model had an adjusted R^2 of 0.726 after the control variables, which changed to 0.727 (Sig. < 0.001) when the KOA variable was added in the second block. This implies that the contribution of KOA to the overall price model is negligible. However, the tolerance statistic of 0.911 shows that the KOA variable is practically orthogonal to the other variables, which implies that its contribution is unique and not captured by all the other variables. The main goal of adding the KOA variable to the model is not so much raising the R^2 of an econometric model of flower prices, but rather it is establishing the existence of a theoretical effect. As can be seen in table 4.4, the coefficient for KOA is negative and significant, yielding support for hypothesis 4.1.

Table 4.5 contains cross-correlations and table 4.6 contains the results for the regression of the second model, with the KOA buyers split in internal KOA buyers (KOAINT) and external KOA buyers (KOAEXT). This model also had an adjusted R^2 of 0.726 after the control variables, which changed to 0.727 (Sig. < 0.001) when the KOAINT and KOAEXT variables were added in the second block. As in the previous model, the contribution to the overall price model is negligible, but the tolerance statistics of 0.971 and 0.931 respectively, indicate that both variables are practically orthogonal to the other variables, thus capturing a unique contribution. Similarly, the main goal of adding the KOAINT and KOAEXT variables to the model is not so much raising the R^2 of an econometric model of flower prices, but rather it is establishing the existence of a theoretical effect.

Table 4.5 Cross-correlations KOA model 4.2

	PRICE	VBN	DIAM	QUANT	MON	TUE	WED	THU	FRI	KOA INT	KOA EXT
PRICE	1.000										
VBN	.524*	1.000									
DIAM	.530*	.026*	1.000								
QUANT	-.232*	-.044*	-.231*	1.000							
MON	.043*	.004	.016*	-.002	1.000						
TUE	.023*	-.016*	.042*	-.009*	-.353*	1.000					
WED	-.058*	-.022*	-.024*	.003	-.312*	-.245*	1.000				
THU	-.037*	.015*	-.042*	.025*	-.167*	-.131*	-.116*	1.000			
FRI	.003	.022*	-.014*	-.005	-.373*	-.293*	-.259*	-.138*	1.000		
KOAINT	-.061*	-.005	-.019*	.110*	-.010*	-.019*	.038*	-.002	-.003	1.000	
KOAEXT	.001	.027*	-.029*	.234*	.000	.025*	-.036*	.013*	.001	-.191*	1.000

*. Correlation is significant at the 0.01 level (2-tailed).

Table 4.6 Regression coefficients KOA model 4.2

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	-162.582	3.309		-49.129	.000
TUE	-4.627	.458	-.022	-10.109	.000
WED	-7.263	.488	-.032	-14.881	.000
THU	-6.302	.739	-.017	-8.531	.000
FRI	-2.127	.447	-.010	-4.761	.000
DIAM	13.092	.080	.408	163.106	.000
VBN	1.060	.004	.504	271.094	.000
QUANT	-3.906E-02	.002	-.046	-22.714	.000
KOAINT	-5.094	.436	-.022	-11.680	.000
KOAEXT	.301	.489	.001	.614	.539

The two important coefficients are those for KOAINT and KOAEXT. The first was negative as expected: -5.094. However, the KOAEXT coefficient was marginally positive and not significant, indicating that external KOA buyers paid the same prices as did auction hall buyers. This means that the hypothesis 4.2a is only partially validated, namely only for the internal KOA buyers. Additionally, this means that hypothesis 4.2b has to be rejected, as the internal KOA buyers actually paid *less* than the external KOA buyers.

4.6 Discussion

The results indicate that the first hypothesis is supported, implying that KOA-buyers do indeed pay lower prices than auction hall buyers. However, when KOA-buyers are split into internal and external KOA-buyers, a somewhat different picture emerges. Although the reduced price hypothesis is supported for internal KOA buyers, the situation for external KOA buyers is rather more complicated. First of all, there is the fact that they do not differ significantly from buyers in the auction hall (the rejection of hypothesis 4.2a). A possible explanation could be that the external KOA buyers simply cannot risk trying to pay a lower price. A setting in which this would make sense is if they have an orderbook to fill, i.e. they buy mainly based on orders from their customers. In that case they do not want to run the risk of not being able to deliver the flowers to their customers, so they compete with the auction hall buyers and end up paying the same prices. This may be particularly so if their customers are relatively price-insensitive. This type of selection bias with respect to purchasing strategy cannot be excluded with the current data available.

The second surprising finding is the reversal of the expected price difference between internal and external KOA buyers. External KOA buyers have an informational disadvantage compared to internal KOA buyers, since they are not able to physically inspect the flowers in the morning before the auction. It was expected that this would lead external KOA buyers to bid lower on average, analogous to the reasoning in Chapter 3. The fact that they actually pay higher prices than internal buyers is hard to explain. Internal KOA-buyers tend to be much larger (in terms of overall purchasing volume) than external KOA-buyers. This means that there could again be a selection bias involved, if larger buyers are more shrewd bidders and therefore pay lower prices or if overall size is correlated with the general purchasing strategy (transaction size itself is controlled for via the QUANT variable). To elaborate a little on the latter: if internal KOA-buyers tend to buy less 'on order' than external KOA buyers, and more for speculative reasons ('cherry picking') they are likely to pay lower prices on average since they will only bid if market conditions are particularly favorable.

An explanation other than unobserved bidder heterogeneity may have to do with the concept of market state information described earlier. As mentioned in paragraph 4.3, internal KOA-buyers had access to the video security system. This gave them information that external KOA-buyers lacked. For instance if there was an interruption in the auctioning process, internal KOA-buyers could see whether this was due to a mechanical defect or other reasons. Or, information more relevant to their bidding behavior: internal KOA-buyers could see how many people were in the auction hall. This would allow them to more accurately assess the total demand and competition than external KOA-buyers, who only had information about the total supply. Essentially, external KOA-buyers have to pay a premium to cover the increased uncertainty about the market state if they still want to win the auction, because they have to make a conservative (i.e. high) estimate of the number of bidders they are competing against, which biases their bids upwards.

4.7 Conclusions

This chapter investigated empirically the differences in bidding behavior between traditional bidders in flowers auctions and bidders who bid from their offices using an ISDN linkup (KOA bidders). As both types of bidders participated in the exact same auctions, this allows for a detailed, direct comparison between these two categories of bidders.

The only a priori established differences between the bidders are reduced search and switching costs and reduced availability of market state information for the electronic bidders. This is hypothesized to lead to lower prices (Bakos, 1991, 1997). The effect of the reduction in market state information was initially expected to be negligible compared to the search and switching cost effect. The resulting reduced price hypothesis was tested using the transaction database of the same flower auction as investigated in chapter 3. The results from a regression model yield support for this hypothesis as electronic bidders do indeed pay lower prices.

The electronic bidders could be split in bidders who had an office on the auction complex itself and bid from there (internal KOA buyers) and bidders who did not have such an office and therefore bid from their offices outside the auction complex (external KOA buyers). The internal KOA buyers had an information advantage on product quality, because they could inspect the flowers in the auction warehouse before the auction started and they had access to the security camera system, which in particular gave them some extra information about the number of bidders present. External KOA buyers lacked this extra market state information. A second model was constructed to investigate the differences between these two categories, where external KOA-buyers were expected to pay a lower price (as in the first model, the effects of reduced market state information were expected to be negligible to the main effect of product quality information). Results from this second regression model indicate that the reduced price effects found in the first model are due only to the internal KOA buyers. In the model, external KOA buyers turn out to pay the same prices as buyers in the auction hall. This implies that the benefits of lower search and switching costs for external KOA buyers do not show up in the prices they pay and the information disadvantage they have compared to internal KOA buyers is of no consequence either. This runs counter to initial theoretical predictions. Two main explanations for this are suggested. The first is that there is a selection bias among the KOA-bidders that the current data cannot control for: for example, external KOA-buyers may tend to buy 'on order', whereas internal KOA-buyers may tend to buy only if market conditions are particularly favorable (cherry-picking). If buyers have an orderbook to fill for their customers and they do not want to run the risk of having to sell 'no', they can be expected to be less price-sensitive, particularly if their customers are not very price-sensitive either. This could result in higher prices being paid by orderbook buyers, in this case the external KOA buyers.

The second explanation is that the market state information mattered much more than expected: because external KOA-buyers cannot see the number of bidders in the auction hall, they cannot assess total demand as accurately as internal KOA-buyers and therefore they have to pay a bid premium to account for this increased uncertainty of being able to win the auction.

Further research is obviously needed, and particularly more detailed data needs to be collected about bidders and their general purchasing strategies (orderbook vs. cherry-picking) to at least partially control for bidder heterogeneity. In any case, it seems safe to say that the effects of reduced search and switching costs are not as straightforward as current theory suggests, particularly when the effects of product quality information and market state information are taken into account. This chapter also suggests information itself is a multidimensional construct: different types of information have different effects. Aggregating those into a single dimension of information (like in the hypotheses 4.2a and 4.2b for instance) may obscure important underlying regularities. In particular the role of market state information looks to be more important than initially assumed. The results suggest that a reduction in market state information may lead to bidders paying higher prices in electronic markets, but this hypothesis needs further testing.

CHAPTER 5 : INFORMATION ARCHITECTURE AND ELECTRONIC MARKET PERFORMANCE IN MULTIDIMENSIONAL AUCTIONS[6]

5.1 Introduction

The two previous chapters dealt with electronic markets in which ICT was 'added' to existing market processes. However, automating existing market processes is only one side of the ICT coin. The other side is that ICT offers the potential for redesigning markets to achieve gains for all stakeholders involved. One such potentially promising new market is the multidimensional auction (Koppius, 1998; Teich, Wallenius and Wallenius, 1999; Bichler 2000). In a multidimensional auction, bidders bid not just on price, but on the underlying value drivers such as quality, delivery time and warranty as well, so these value drivers are the dimensions in a multidimensional auction. The reasoning behind this is that (unless budgets are very limited) price is not so much a decision criterion in itself, but rather a means to summarize and compare differences in the value drivers. Value to the buyer is derived from the underlying value drivers, not from the price itself (Lancaster, 1966). For instance, when buying a car, the actual value to the buyer is derived from a variety of aspects such as comfort, speed, safety, size, color, brand, having a reputable dealer nearby, gas mileage, engine quality, automatic gearbox vs. stick-shift, power steering, et cetera. These value drivers determine what the car is worth to the buyer, in other words: what he would be willing to pay, assuming that he has the necessary budget. The multidimensional auction turns this process upside down: instead of offering a fixed constellation of features (i.e. a particular car) and leaving the buyer only to decide on the price he is willing to pay for that car, the potential buyer 'auctions his budget' (so to speak) to potential suppliers. These suppliers then can modify the features they offer to the buyer (for instance by adding power steering at no extra cost or offering a slightly slower car, but at a substantial price reduction) as each supplier tries to maximize the value to the buyer to increase their chance of winning the auction, while maintaining their profit margin.

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[6] This chapter is based partially on Koppius (1998) and Koppius, Kumar and van Heck (2000).

By summarizing the multiple dimensions of value in a single value of price, traditional one-dimensional auctions ignore the fact that some bidders may have different preferences (or costs) regarding certain dimensions. Such bidder heterogeneity leads to comparative differences between buyer and seller on the weight of some dimensions. This may lead to a situation where there was potential for improvements for all parties involved, yet this potential was not realized. A simple example will illustrate this. Suppose the buyer holds a single-dimensional procurement auction with quality fixed at 'A' and delivery time at 2 weeks, resulting in a price of 100. Although the buyer may be content with this bid, he might have been willing to pay an extra 10 for a faster delivery of 1 week instead of 2 weeks. If the extra cost of this faster delivery to the winning bidder is only 5, both parties would be prefer still having quality 'A', but now with delivery time 1 week and a price of 107. In this case, the buyer was willing to pay 10 extra for faster delivery but only pays 7 extra, whereas the extra cost of faster delivery to that supplier is 5, but he receives 7 extra, so both parties are better off compared to the original winning bid. Similarly, suppose the buyer was willing to accept a lower quality 'B' if the price would drop by at least 5 and the winning bidder could deliver quality 'B' at a price 10 cheaper than quality 'A', again opportunities exist for Pareto improvements. However, in a one-dimensional auction on price (so all the other dimensions are fixed), bidders are unlikely to find out about such mutually beneficial tradeoffs.

Although a reverse (procurement) auction is the most natural candidate for a multidimensional auction, the principle can be applied to a standard forward auction as well. In that case, the specification of the product itself is fixed, but there are still several accompanying services such as delivery, terms of payment or in some cases maintenance and warranty policies that have to be agreed upon between buyer and seller. Instead of fixing these in advance, these could be made part of the buyer's bid as well.

In short, a multidimensional auction moves beyond the purely distributive aspects of traditional auctions where a bidder's loss is the bid taker's gain, to incorporate integrative aspects that can capture the "money left on the table" (Bazerman, Magliozzi and Neale, 1985; Rangaswamy and Shell, 1997). It is this new, ICT-enabled market that this chapter will investigate.

The two previous chapters showed that the various types of information flows in a market are important determinants of market processes. This chapter formalizes that intuition in the concept of the information architecture of the market. The information architecture describes what type of information is available to whom, or when and how it becomes available to whom during the market process. This will be the main independent variable of interest as this study will test the consequences of different information architectures for market performance in a multidimensional auction, using laboratory experiments.

The next paragraph will give the theoretical background on the role of information architecture in a market and review the existing literature on multidimensional auctions. Paragraph 3 outlines a general model of multidimensional auctions that, after the to-be-tested hypotheses are introduced in paragraph 4, will form the basis for the experimental design described in paragraph 5. The results are described in paragraph 6, with the discussion and conclusions in paragraph 7. The last paragraph contains an appendix with the statistical output.

5.2 Theoretical background

In a market, it is not so much supply and demand itself that is exchanged, but information regarding supply and demand, which eventually leads to exchange (Hayek, 1945). Furthermore, a market does not trade, its traders do and they exchange information in order to do this. The competition process, as facilitated by the market, allows traders to discover information about potential competitors and exchange opportunities. Competition does not exist in a vacuum however. Competitive behavior is influenced by law (for instance antitrust law), social norms (for instance regarding fairness, see Kahneman, Knetsch and Thaler (1986)) and the formal rules of the market itself, for instance regarding eligibility of bids and offers or the disclosure of information in the market (O'Hara, 1995). The focus of this chapter is on the third category, the formal market rules (which form a part of the information architecture as defined earlier) and what their impact is on market performance.

Although information architecture plays a role in any type of market (O'Hara, 1995), because of the increased cognitive complexity of bidding over multiple attributes instead of just price (Rangaswamy and Shell, 1997), information is expected to play an even more crucial role in a multidimensional auction, compared to one-dimensional (price) auctions.

Stark (1974) made one of the earliest contributions to multidimensional auctions when he investigated unit price bidding for highway building contracts. In unit price bidding, bidders are bidding for a contract that consists of multiple, distinct items, each with the bid taker's estimate of the necessary quantity (for instance, the amount of asphalt needed). Bidders then submit a multidimensional bid, consisting of unit prices for each of the individual items (such as price per unit of asphalt). These are then multiplied with the estimates to calculate the total proposal value and the lowest bidder usually wins the auction. However, the bidders are not paid according to the estimated quantities, but according to the realized quantities. This means that bidders, who have different estimates of quantities for certain items than the bid taker, may manipulate their unit prices. For instance, suppose a bidder estimates that he needs 10% more asphalt for the road than the bid taker estimated (perhaps because he has better knowledge of local conditions). He will then submit a unit price higher than the price he would have bid if his quantity estimate and bid taker's concurred. To keep the total cost of the contract constant (to not reduce his chance of winning the auction), he will lower his unit prices for one or more of the other items. Because the bidder is paid according to the *actual* quantities used, the extra profit from a higher unit price on an underestimated quantity may outweigh the profit loss from the units with a reduced unit price. This manipulation of unit prices by bidders is called unbalanced bidding. Stark (1974) developed a decision model to help bidders maximize their net profit using such unbalanced bidding. In their analysis of mineral leasing, Rothkopf and Engelbrecht-Wiggans (1992) point to the potential benefits of bidding on multiple dimensions instead of the usual price or royalty schemes and they suggest a bid scoring system that avoids unbalanced bidding. In a related analysis, Samuelson (1986) looked at contract bidding in general and emphasized the fundamental tradeoff between efficient firm selection and sharing the risk of costs misestimates. If no risk is shared on the part of the bid taker (a fixed-price contract), bidders will submit balanced bids, but require a higher profit margin. On the other extreme, if the bid taker assumes all risk (a cost-plus contract, so bidders only submit profit margins as bids), the lower profit margin will win the auction, but possibly at higher total cost. He shows that there is some optimal incentive contract in between these extremes. He notes that this analysis extends to contracts where multiple dimensions are involved, although he does not provide an analysis of optimal contract design for the multidimensional case.

Thiel (1988) analytically investigated an isolated, multidimensional procurement auction in which the bid taker has a fixed budget that is known in advance and furthermore does not value any savings (no repeat business). In that particular setting, the multidimensional case reduced to the one-dimensional case of a normal auction without loss of generality, so there would be no need to investigate multidimensional auctions separately. Unfortunately, the assumptions under which his result holds are not entirely realistic from a practical point of view: for instance, the bid taker will certainly value any savings.
Che (1993) looked at three different auction mechanisms for two-dimensional auctions (on price and quality), based on actual practices at the US Department of Defense. The three mechanisms were first-score, second-score and second-offer. In all mechanisms, bidders are ranked based on the bid taker's scoring rule and the winner is the bidder with the highest score. In a first-score auction, the winner simply fulfills his bid. In a second-offer auction, he fulfills the bid of the second-highest bidder, whereas in the second-score auction he can choose his own bid as long as he matches the score of the second-highest bidder. Che showed that under certain circumstances the three investigated mechanisms yield the same expected revenue and that in all circumstances, quality is either undervalued or overvalued from the buyer's point of view. In his analysis, he assumed that the costs of the bidding firms were independent. Branco (1997) extended Che's analysis by deriving an optimal auction mechanism for the more realistic case when the bidding firms' costs are correlated, although both still assume that the buyer has perfect knowledge of the bidders' cost structures. Cripps and Ireland (1994) approached the problem from a slightly different point of view when they investigated auctions in which the bid taker sets threshold levels for the various characteristics that are not known to the bidders. They analyzed three different bid evaluation schemes, partially based on the tendering of UK television licenses. The difference between the schemes was the order in which each bid was evaluated (price first, quality second; quality first, price second; price and quality simultaneously) and they found that the three schemes produced the same results. Milgrom (2000) showed that a multidimensional version of the Vickrey auction achieves the efficient auction outcome if the auctioneer announces his true utility function as the scoring rule by which bids are evaluated.

These are all analytical results, but as electronic multidimensional auctions are slowly becoming more used in practice (some examples are Ebreviate.com, Perfect.com and Frictionless.com), recently also papers have started to appear that have empirical evidence. Teich and colleagues (Teich, Wallenius and Wallenius, 1999) provide a critical analysis of Optimark's (www.optimark.com) price-quantity market mechanism. Although technically speaking it is a multi-unit auction, because price and quantity of traders are jointly evaluated (as opposed to price only in most multi-unit auctions), it takes on a multidimensional flavor. They point to the important issue of preference elicitation and argue that the procedure Optimark uses is too complicated and suggest a simpler procedure. They also suggest some improvements to Optimark's matching algorithm. Later, they developed a novel combination of multidimensional negotiations and auctions in a single mechanism, the Negotiauction (Teich, Wallenius, Wallenius and Zaitsev, 2001). Bichler (2000) used laboratory experimentsto confirm the logically intuitive suggestion that multidimensional auctions yield a higher utility outcome than single-dimensional auctions, a result that was later also confirmed in simulations (Bichler and Klimesch, 2000).

In general, there are two different basic bidding mechanisms the bid taker/auctioneer could employ for a multidimensional auction: a sealed-bid mechanism (such as a first-price or second-price sealed bid auction) or an open outcry mechanism (such as the English auction)[7]. In particular, the first-price sealed-bid case is common in practice, with many procurement or tendering situations requiring potential suppliers to submit a bid on various dimensions. A traditional open outcry version of a multidimensional auction is rare. One of the reasons for this is that the open outcry model would be very costly in terms of communication compared to submitting a single bid, unless the bidders all congregate in one place, which is rather cumbersome, particularly when dealing with a geographically dispersed set of suppliers. However, one of the disadvantages of a single-shot auction is that there is no opportunity for the bidders to react to other bids, but instead estimates of other bidders strategies have to be used. For instance, FreeMarkets claims on their website (www.freemarkets.com) that they achieve savings of up to 25% when using a reverse English auction instead of a single-shot auction. Since most procurement

[7] Although bidding a one-dimensional score is of course possible in a Dutch auction setting if the scoring rule is published, it is not obvious how a Dutch auction can be generalized to allow multidimensional bidding on more than two dimensions.

auctions contain common value elements, this claim is in line with Milgrom and Weber (1982). But even if they were modeled as independent private value auctions, perhaps because of the idiosyncratic nature of the product, an explanation for this difference between open outcry and sealed-bid auctions can be given, as done by Engelbrecht-Wiggans (2001). He argues that because bidders face uncertainty regarding a number of factors such as the exact value of the object (except in the case of fully independent private values), details of the auction rules, the number of bidders participating and their expected valuations, bidders will acquire information to resolve this uncertainty to a satisfying degree. The need for or cost of acquiring this information is lower in oral (open outcry) auctions than in sealed-bid auctions, which implies greater entry in oral auctions, leading to more competition and therefore higher prices (or lower prices in the reverse auctions of FreeMarkets). He shows that this result holds even in the case of independent private values.

The complexity of a multidimensional setting means that the potential benefits of being able to react to your competitor's bid are even more important. Therefore we focus on an open outcry setting. This line of reasoning is similar to one of the rationales for the FCC auction design (Cramton, 1995) and Engelbrecht-Wiggans (1988) showed that a multi-stage setting might be beneficial for the auctioneer as well. An open outcry version of the multidimensional auction not only gives the bidders the opportunity to react to other bidders, but more importantly they have more options to explore the highly complex bid space of multidimensional auctions with all its potential tradeoffs.

This does lead however to the question of what information feedback should be given to the bidders about their competitors' bids (and other aspects of the bidding) so that they can react in an appropriate way. This is precisely what is determined by the information architecture of the market.

For instance, the feedback given to the bidders may include the scoring rule that the auctioneer uses to evaluate the bids, information on their own bid, such as their bid score or bid ranking, but also information on other bidders' bids. The information feedback may be public or private or a mixture of the two. Finally, if bidding occurs synchronously, meaning that the auction becomes a multi-round auction, all bidders have to submit a bid before feedback is given as determined by the information architecture and the next bidding round commences. Bidding may also occur asynchronously and feedback is given after each newly submitted bid, again based on the information architecture.

To show that information architecture is relevant in a multidimensional auction, we will first describe a very simple deterministic situation. Assume a procurement setting where there are two dimensions, namely price and delivery time. There are two bidders competing for the order through an English auction. Bidder 1 can deliver d_1 = ”on time” at a price of p_1 = 900. Bidder 2 on the other hand can deliver d_2 = ”early” at a price of p_2 = 1000. Suppose the bid taker values earlier delivery at the price equivalent of 10. If the bid taker truthfully reveals this information, the end result will be that bidder 1 will win with a winning bid of 989. However, suppose the bid taker would tell the bidders he values earlier delivery by 90. Bidder 1 would still win, but now with a winning bid of 909 instead of 989.
Although the example is not particularly realistic since it assumes complete information on the bid taker’s side for instance, it does show that different information architectures do have an impact on the outcome of the auction. As an aside, it also shows that sometimes the bid taker can profit from misrepresenting his private information. Generally, misrepresentation is profitable for the bid taker when used to push the most efficient bidder to the limit, effectively by ‘subsidizing’ the second-most efficient bidder (Rothkopf, Harstad and Fu, 1997).

For a more general case that illustrates the importance of information, see figure 5.1 for a two-dimensional auction with a bid being made on price and delivery time. A particular bidder makes a certain two-dimensional bid B. Two iso-utility curves are drawn, one for the bidder, one for the bid taker. The bid corresponds an intersection point of the two curves and the curves correspond to the utility of the bid being made by that particular bidder. The arrows indicate the direction of utility improvement for each party. The bid taker (i.e. buyer) prefers a lower price and a faster delivery time, the bidder (i.e. seller) prefers a higher price and a later delivery time. Note that for simplicity’s sake we have assumed no further restrictions on the attributes, such as a maximum price the bid taker is willing to pay or a minimum delivery time the bidder can meet for instance. These might prevent certain areas in figure 5.1 from being feasible bids for both parties.

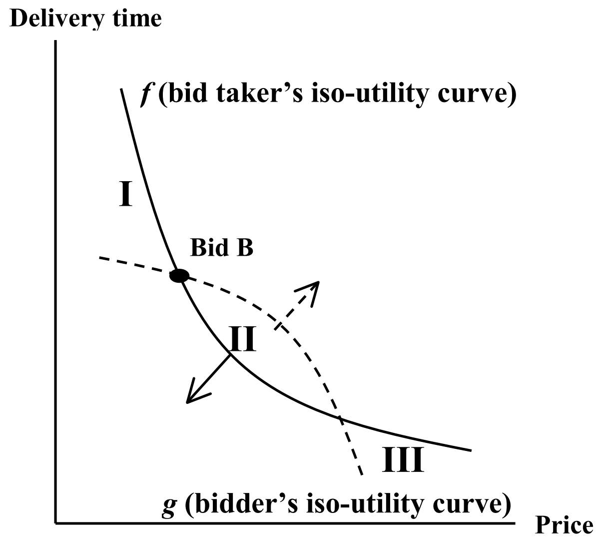

Figure 5.1 Tradeoffs in a two-dimensional auction

So in this case, with the bid B corresponding to one of the intersections of the two iso-utility curves, areas I and III are areas in which any revised bid would yield increased utility for both parties. A revised bid in area II would yield decreased utility for both parties. A revised bid in the remaining areas would yield a utility increase for one party and a decrease for the other party. The important question now is: how does the bidder know to revise his bid in direction of area I or III and not in any other direction? For that, he has to has some information available for him to know that, which illustrates the relevance of information architecture.

Another reason to investigate the effects of different information architectures is that using a publicly announced utility function as scoring rule of the bids sometimes is not possible or desirable. For instance, announcing a utility function may give monopoly power to one or more bidders, yet it may be illegal for the bid taker to misrepresent it (for instance in government procurement) if he wants to avoid this monopoly effect. In some cases, the bid taker may want to discriminate against or for particular bidders for certain reasons (legal or not), but does not want this to become known. Or the bid taker may have only an approximate utility function, instead of a precise one, which could lead to a sub-optimal outcome

because bidders now optimize against the 'wrong' scoring rule. Or the bid taker may not even have an explicit utility function to begin with, and instead only be able to do pairwise comparisons[8]. Given such potential problems with publicly announcing a scoring rule, alternative information architectures in which the scoring rule can remain secret, are worth investigating to see if satisfactory outcomes can still be attained.
A final reason is that, particularly for auctions, it is an area that has received little attention thus far, both from theorists and experimentalists (Kagel, 1995, p.520-521). Yet with the increasing popularity of auctions and in particular the more complex electronic auction mechanisms enabled by ICT, the information architecture becomes an increasingly useful design parameter.

Different market types have different types of information that is (potentially) available, so the particulars of an information architecture vary from market to market. Specifically, a multidimensional auction has five categories of information elements:

1. Bid elements
2. Bid scores
3. Bid rankings
4. Bid taker's utility function
5. Bidder identities

The first category gives information regarding the bids themselves. This could be the actual bids that were submitted, but an interesting policy would be to not reveal information about the bids received and instead give each bidder a number of alternatives that would top the current highest bid (or perhaps merely improve on their current bid). Revealing bids is usually done in conjunction with elements of categories 2 and 3, such as revealing the highest bid, i.e. the highest-ranked bid.
The second category refers to the revelation of the scores of a bid, with score being the bid taker's utility. Note that (bearing in mind the information manipulation example given earlier) the utility revealed need not necessarily correspond to the actual utility of the bid taker, since misrepresentation may be

[8] Note that using pairwise comparisons will only be equivalent to using a utility function when an unlimited amount of pairwise comparisons can be done accurately at zero cost.

profitable. Also note that revealing a utility is only meaningful if the scale of the utility is (partially) known to the bidders.

The third category reveals information about the relative ranking of the bid among all bids received, based on the bid taker's (possibly misrepresented) utility. This information can be enhanced if the total number of bids received is revealed as well.

The information from the second and third categories in principle allows bidders to make partial inferences about the bid taker's utility function after a number of rounds. However, the bid taker can also choose to reveal some information about his utility function directly and that is the fourth category. He may choose to reveal the utility function entirely, but another option might be to reveal the direction of fastest improvement upon the current bid. This corresponds to the normal vector of the utility curve at the bid point (see also the arrows in figure 5.1).

The fifth category constitutes the revelation of the identity of the bidders. The identity of the highest bidder will generally be revealed only at the end of the auction, but it is of course possible to reveal the identity of the current high bidder during the auction. In other cases, one may want to have a completely public auction in which the identity of each bidder is known at all times.

To analyze the effects of different information architectures on the performance of the auction mechanism, we need criteria by which to judge market performance, as this can be measured in different ways (O'Hara, 1995). Two measures that are particularly relevant in this case are Pareto optimality and winner efficiency. Pareto optimality in a multidimensional auction is measured at the dyad level of (winning) bidder-bid taker. A (winning) bid is Pareto optimal if no feasible bid can be made which is a Pareto improvement, i.e. no mutually beneficial bids exist for the bid taker and that particular bidder. This does not necessarily mean that the bid taker's utility is maximized. Winner efficiency is achieved when the most efficient bidder makes the actual winning bid. In standard one-dimensional auctions, winner efficiency is achieved when the bidder with the highest valuation wins the auction. In the reverse case under consideration here, it means that the bidder with the lowest cost structure wins the auction. So a multidimensional auction is efficient if, given a winning bid, there does not exist a different bidder who could make a feasible bid (feasible for both parties) that would improve the bid taker's utility. Loosely speaking, efficiency ensures that the eventual trade occurs between the ‘right’ trading partners, optimality ensures that the total surplus of that trade is maximized.

Note that in a multidimensional auction, a winning bid can be Pareto optimal, yet at the same time not winner efficient and vice versa. An optimal, inefficient winning bid can occur when the winning bidder has Pareto-optimized his own bid relative to the bid taker’s utility (no Pareto improvements possible, areas I and III in fig. 5.1 are not feasible), yet there may be a different bidder that could outbid him (winner inefficiency), but that bidder has not made such a bid. A non-Pareto-optimal, winner efficient winning bid can occur when there are no bidders that could outbid the current highest bidder (winner efficient), yet his current bid could be Pareto-improved upon by himself (areas I and III in fig. 1 are feasible, yet not being bid in). In both cases, the complexity of the bid space and unfamiliarity with the bid taker’s preferences lead to performance degradations that could be ameliorated by giving proper feedback, i.e. a well-designed information architecture. To relate the information architecture to these two performance measures, we need to distinguish between two different types of information that exist in a market: supply-side information and demand-side information. In a reverse auction, information about the supply-side gives the bidder information about the other bidders and more precisely: about the state of competition among the bidders. The more this type of information is available, the more transparent the competition process becomes and the more likely it is that the most efficient bidder will actually win the auction (assuming no information manipulation by the bid taker). Stated in general terms:

Proposition 5.1: A market with an information architecture that reveals more information about the state of competition will have a higher likelihood of achieving winner efficiency.

In a reverse auction, information about the demand-side gives the bidder information about the bid taker’s preferences and more precisely: about the direction in which to improve his bid. The more this type of information is available, the more fully known the bid taker’s preferences are and the more likely that opportunities for win-win improvements will be exploited. Stated in general terms:

Proposition 5.2: A market with an information architecture that reveals more information about the bid taker's preferences will have a higher likelihood of achieving Pareto optimality.

As an illustration of these propositions, table 5.1 outlines several information architectures for a multi-round, reverse, multidimensional auction, describing which information is revealed at the end of each round. Based on how much information each information architecture reveals about the state of competition (supply-side) and the bid taker's preferences (demand-side), each of them is rated on their expected Pareto optimality and winner efficiency. These are only rough and qualitative ratings, used merely to give an impression of how various information architectures would compare to each other (o = average, - = below average, + = above average). In this table, feedback policies dealing with whether or not to reveal bidder's identity are left out, as the effects of that are indeterminate to the best of my knowledge.

Table 5.1 Information architectures and their relative effect on Pareto optimality and winner efficiency

Information architecture	Optimality	Efficiency
Bid highest? (yes/no)	-	-
1 alternative	o	-
n alternatives (n relatively large)	+	o
Rank of bid	-	+
Highest bid	o	+
All bids + ranking	+	+
Bid score + highest bid score	-	o
Bid score + all other bid scores	-	+
Bid taker's utility function	+	-
Direction of fastest improvement	+	-

5.3 A model of multidimensional auctions

A natural setting for a multidimensional auction is a procurement setting, where suppliers bid to satisfy a demand from the buyer (the bid taker). As noted before, the essential feature of the multidimensional auction is that the product to be procured is not exhaustively specified in advance, but instead is endogenized into the auction process.

Consider the following simple procurement model, taken from Koppius, Kumar and Van Heck (2000) in which there is one buyer (i.e. bid taker) and *n* suppliers (i.e. bidders). The bid taker has *K* attributes on which the buyer must bid in order for a bid to be valid, hence all bids must be *K*-dimensional vectors. The attributes may be any combination of monetary and non-monetary attributes. Possible attributes can include a fixed-price component, a variable-price component, quantity offered, delivery time, various product quality attributes and issues such as warranty policies.

A bid is denoted by $\mathbf{b} = (b_1;...;b_K)$ with each separate b_k denoting the level of attribute *k*. The bid taker has a private utility function $U(\boldsymbol{b})$ that denotes the utility he derives from a bid; this function converts both monetary and non-monetary attributes into a utility. The bid taker can choose to reveal his utility function or, as doing this may reveal sensitive competitive information, he can keep it secret and perhaps reveal other information.

The bid taker has several constraints $\beta_s(\boldsymbol{b})$ (s = 1,…,S) regarding the values of the attributes, resulting in a feasible bid region for the bid taker denoted by ***BR*** (this is somewhat analogous to the reserve price in standard auctions). These constraints may be simple minimum or maximum values or more complex functions describing some of the tradeoffs between attributes (say for instance the maximum price increase for faster delivery, possibly dependent on the quality level). Disregarding concerns for future interactions and fairness, the bid taker would like to maximize $U(\boldsymbol{b})$ s.t. $\mathbf{b} \in \boldsymbol{BR}$. Similarly, each bidder *i* faces several constraints $c_{i,w}(\boldsymbol{b})$ (w = 1,…,W) regarding the sets of attributes that he can offer, resulting in a feasible bid region for each bidder denoted by $\boldsymbol{BR_i}$. These are constraints that have to do with internal production function, minimum price levels etc. They are assumed to be private information, but not necessarily independent. Each bidder has a utility function $\pi_i(\boldsymbol{b})$ and tries to maximize $\pi_i(\boldsymbol{b}).Prob(\boldsymbol{b}=winning\ bid)$ s.t. $\mathbf{b} \in \boldsymbol{BR_i}$.

5.4 Experimental design

The experiment took place in the context of a procurement setting in the chemical industry, where bidders were suppliers of hydrochloric acid. Although traditionally experimental auction research is done as context-free as possible, given the cognitive complexity of a multidimensional auction, it was felt to be better to include a context (described as neutrally as possible though). The number of dimensions was set to K=3, more specifically price p, quality c (the contamination percentage) and delivery time t (in days), so $\boldsymbol{b} = (c, t, p)$. The bid taker's utility function changes from auction to auction to represent a new transaction each time. $U(\boldsymbol{b})$ was chosen to have the following general form:

(1) $U(b) = v_1 e^{-c} + v_2 e^{-t} - p^2$

The parameters v_1 and v_2 were varied in each auction to model the tradeoffs that that particular buyer/bid taker would make between quality, delivery time and price. Both v_1 and v_2 were restricted to negative values, to insure that $U(b)$ would be monotonically decreasing in each separate variable, i.e. bids with higher contamination (or delivery or price respectively) are ceteris paribus worse for the bid taker. The bid taker's utility functions were kept secret from the bidders throughout the experiment, although they were told that it would change from auction to auction and would reflect different tradeoffs among the attributes, thus resulting in a potentially different optimal bid.

For simplicity reasons, the constraints regarding feasible bid regions for the bid taker and all bidders were identical:

(2a) $2 \leq c \leq 10$

(2b) $1 \leq t \leq 5$

(2c) $40 \leq p \leq 110$

All three variables were discrete, to further narrow down the bid space and thus reduce the complexity for the bidders. The profit function for bidder i was:

(3) $\pi_i (c, t, p) = p_i - f_i(c_i, t_i)$

In this profit function, p_i indicates the price bid by bidder i and $f_i(c_i, t_i)$ indicates the production costs for bidder i of supplying the product with attributes c_i and t_i. The production cost function had the general form:

(4) $f_i(c_i, t_i) = a_{1,i} - a_{2,i} c_i - a_{3,i} c_i^2 - a_{4,i} t_i - a_{5,i} t_i^2$

Each bidder faced different $a_{j,i}$, to create bidder heterogeneity through different cost functions (e.g. the equivalent of private values in standard auctions). The cost function parameters were chosen such that each bidder has a comparative advantage in a different region of the bid space to partially model a realistic setting of bidder heterogeneity. For instance, one bidder had a cost advantage on fast delivery, whereas another bidder had a cost advantage on delivering low quality. The utility functions used in each auction were subsequently chosen to –in combination with the different cost structures- yield a different, unique maximal bid in each separate auction. For instance, one bid taker/buyer was willing to pay a lot for high quality, but was fairly indifferent to delivery time, whereas another was primarily looking for a cheap product with a fast delivery time. This maximal bid is the benchmark to assess the efficiency of the auction.

The multidimensional auction model was implemented in a software prototype, designed to be run over the Internet, needing only a browser on the client's side. Figure 5.2 shows a screenshot of the bidding screen. The experiment itself was not run over the Internet however, but with subjects located in a dedicated trading room (the Eneco Trading Room at the Rotterdam School of Management) to maximize control over the experimental settings. A copy of the experiment instructions can be found in the appendix to this chapter. Each auction was run as a multi-round auction. In each round, subjects entered their bid on three dimensions in the browser and submitted it to the auction server. Once all bids were received, bidders received on-screen feedback about the current status of the auction as dictated by the rules regarding the information architecture, after which they could submit a revised bid in the next round. The highest bid was defined as the highest bid from all the previous rounds combined, so it was for instance possible that at the end of round 3, the highest bid was a bid submitted in round 2 that simply was not improved upon in round 3. The auction finished after a number of rounds and that number of rounds was public knowledge (displayed on-screen). At that point the highest overall bid won the auction and profits were calculated. Then the next auction started with a different utility function for the bid taker but the same private cost functions for the bidders.

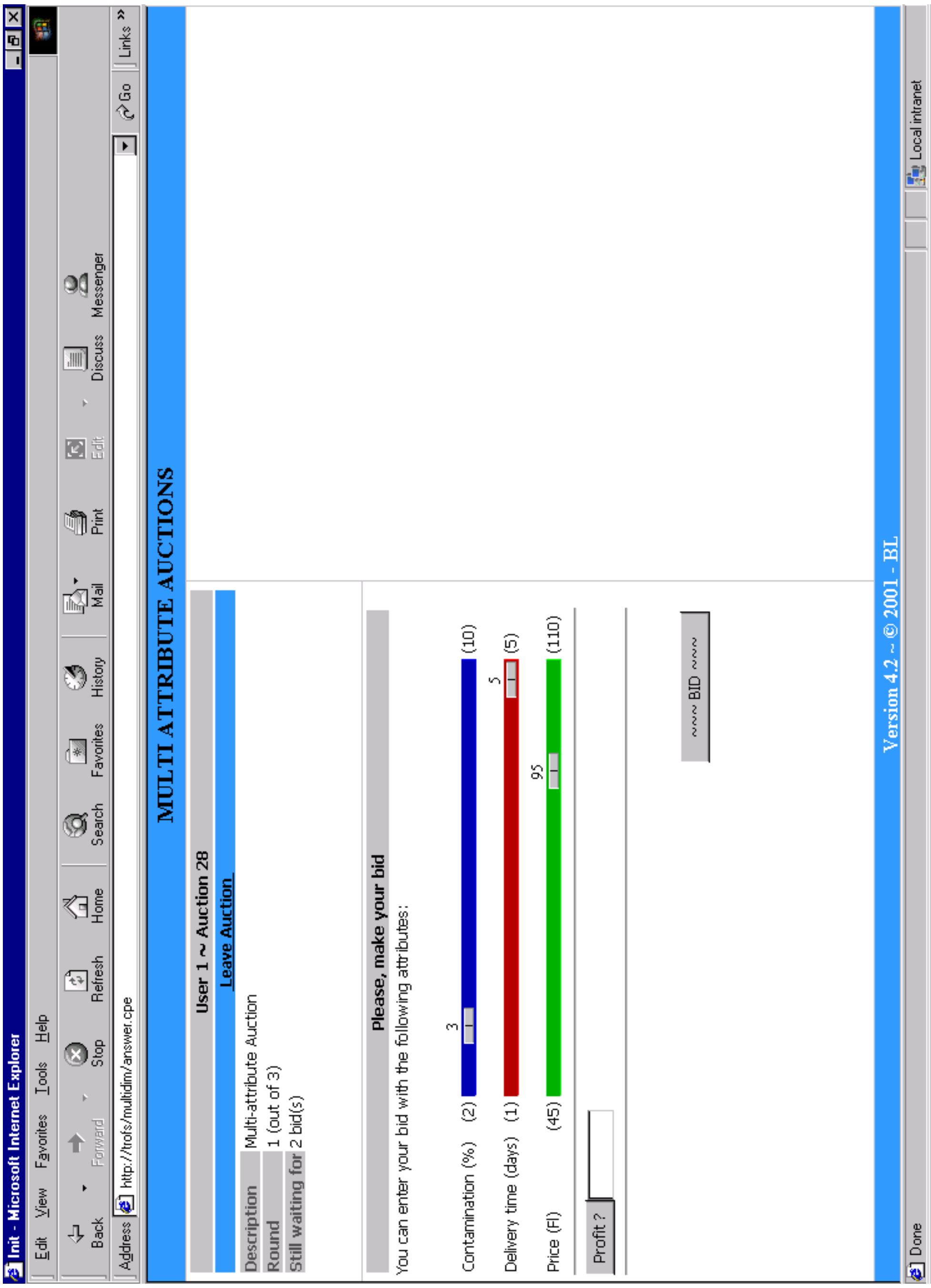

Figure 5.2 Bidding screen

The experiments were run with four subjects (a number not uncommon in experimental auction research, see Kagel (1995)), following a 2 X 2 design. One dimension varied was our experimental variable of information architecture. In one treatment (restricted information architecture), bidders only saw the overall highest bid and bidder at the end of each round. In the other treatment (unrestricted information architecture), bidders saw the overall highest bid and bidder, plus all bids submitted in the latest round (and its bidder) as well as the relative score of each bid as a percentage of the utility of the overall highest bid so far. See figure 5.3 for a screenshot of feedback at the end of the round in an unrestricted information architecture. Compared to the restricted information architecture, the unrestricted case provided more information about the state of competition (such as bid ranking) as well as more information about the bid taker's preferences (such as the relative scores). The second experimental dimension varied was the number of rounds, to allow bidders to better incorporate the available information as the number of rounds increased. One way would be to let the auction itself determine the number of rounds, as done in the FCC spectrum auctions (Cramton, 1995), based for instance on activity rules or minimum bid score increases. Then the experimental condition could be for instance a minimum score increase of 2% versus one of 5%. However, since it was not clear in advance what the exact influence of a longer auction would be in the first place, particularly regarding the effects it might have on how the information is processed, we opted for a simpler approach and simply fixed the number of rounds in advance. Half of all auctions were run over two rounds, half over four rounds. Bidders were informed by the experimenter as well as on the screen before each change in the number of rounds.

The full experiment lasted a little under two hours, including instruction time and two practice auctions to familiarize the participants with the system. The first half of the auctions were run in the following sequence:

A. 3 auctions of 2 rounds with a restricted information architecture,
B. 3 auctions of 2 rounds with an unrestricted information architecture,
C. 3 auctions of 4 rounds with a restricted information architecture and
D. 3 auctions of 4 rounds with an unrestricted information architecture.

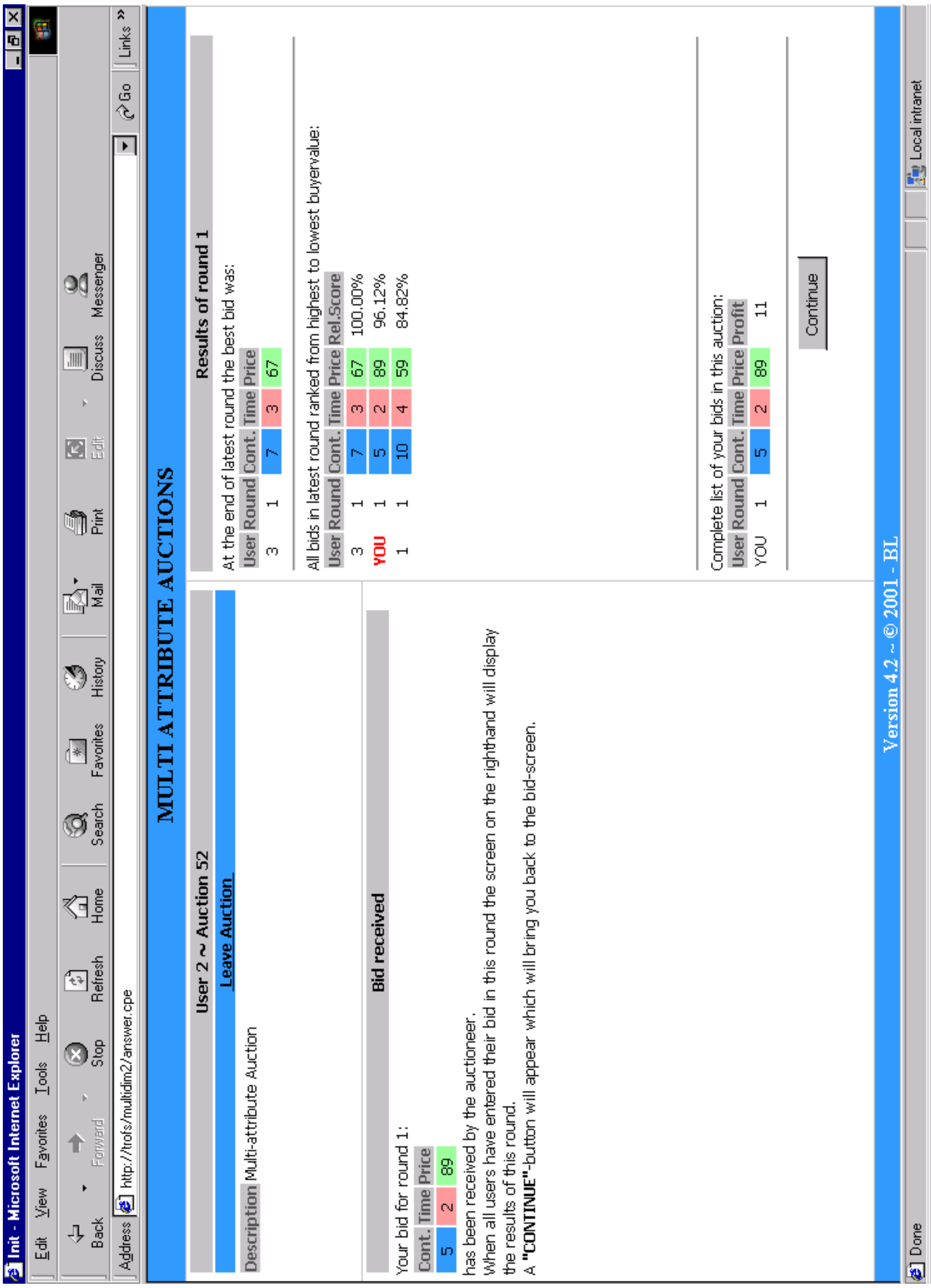

Figure 5.3 Bidder feedback in unrestricted information architecture

The second half of the auctions were run in the reverse sequence to control partially for within-experiment learning effects (an ABCD-DCBA design (Friedman and Sunder, 1993)). The relatively long time needed for each separate auction prevented us from running more than 24 auctions in the two hours available. At the end of the experiments, subjects were interviewed informally about their experiences in the experiment and they were paid their winnings in cash. The winnings ranged from approx. € 7 to € 25, on average € 17.

A replication experiment with the same number of participants was carried out a few weeks later. This experiment had a mirrored auction sequence (a DCBA-ABCD design) to further control for learning effects. Aggregated over the two experiments there are 48 observations, 12 in each cell of the experimental design.

5.5 Measures and hypotheses

Market performance is measured by winner efficiency and Pareto optimality. Two measures of efficiency are used: EFF, which is a binary variable indicating whether or not the winning bid is efficient (1=efficient, 0=not efficient) and TOTEFF, which indicates the distance from the winning bid to the efficient bid (a lower distance indicating higher efficiency). For Pareto-optimality, the main measures are PARETO and NPARETO. PARETO is a binary variable indicating whether or not the winning bid is Pareto-optimal (1=optimal, 0=not optimal), i.e. whether or not there existed a bid that would have made at least one party better off without making the other party worse off. NPARETO is the number of Pareto-improving bids that existed at the end of the auction. A lower value implies an auction that ended close to the optimal bid.

Two additional measures, PARPLUS and NPARPLUS, were also analyzed. They are defined analogous to PARETO and NPARETO respectively, except that the requirement is that now both parties have to be strictly better off, i.e. a higher profit for the bidder and a higher utility for the bid taker.

Bearing in mind propositions 5.1 and 5.2 and the discussion in the previous section about the restricted and unrestricted information architectures, the following hypotheses will be tested:

Hypothesis 5.1a: The average efficiency will be larger in an unrestricted information architecture ($EFF_{unrestricted} > EFF_{restricted}$) .
Hypothesis 5.1b: The distance from the winning bid to the efficient bid will be smaller in an unrestricted information architecture)$TOTEFF_{unrestricted} < TOTEFF_{restricted}$).

Hypothesis 5.2a: Average Pareto optimality will be larger in an unrestricted information architecture ($PARETO_{unrestricted} > PARETO_{restricted}$)
Hypothesis 5.2b: The number of Pareto-improving alternatives will be smaller in an unrestricted information architecture ($NPARETO_{unrestricted} < NPARETO_{restricted}$)
Hypothesis 5.2c: Average strict Pareto optimality will be larger in an unrestricted information architecture ($PARPLUS_{unrestricted} > PARPLUS_{restricted}$)
Hypothesis 5.2d: The number of strict Pareto-improving alternatives will be smaller in an unrestricted information architecture ($NPARPLUS_{unrestricted} < NPARPLUS_{restricted}$)

Changing the number of rounds was primarily manipulated to investigate possible interaction effects between the information architecture and the duration of the competitive process (i.e. the number of bidding rounds). An interaction effect is expected to exist, but no specific hypothesis is formulated a priori regarding direction or magnitude of this possible interactive effect. With regards to the main effect of the number of rounds, the following hypotheses will be tested:

Hypothesis 5.3a: Average efficiency will be larger in a 4-round auction ($EFF_4 > EFF_2$)
Hypothesis 5.3b: The average distance between the winning bid and the efficient bid will be smaller in a 4-round auction ($TOTEFF_4 < TOTEFF_2$)

Hypothesis 5.4a: Average Pareto optimality will be larger in a 4-round auctions ($PARETO_4 > PARETO_2$)
Hypothesis 5.4b: The number of Pareto-improving alternatives will be smaller in a 4-round auction ($NPARETO_4 < NPARETO_2$)
Hypothesis 5.4c: Average strict Pareto-optimality will be larger in a 4-round auction ($PARPLUS_4 > PARPLUS_2$)
Hypothesis 5.4d: The number of strict Pareto-improving alternatives will be smaller in a 4-round auction ($NPARPLUS_4 > NPARPLUS_2$)

5.6 Analysis

Because of the non-normality of the dependent variables, a non-parametric test is used (Tabachnick and Fidell, 2001), in this case the Mann-Whitney test to test for differences between unrestricted and restricted information architecture.

Table 5.2 Descriptives winner efficiency

	N	Mean	Std. Deviation	Minimum	Maximum
TOTEFF	48	.36979	.28709	.000	1.000
EFF	48	.21	.41	0	1

Table 5.3 Descriptives Pareto optimality

	N	Mean	Std. Deviation	Minimum	Maximum
NPARETO	48	41.56	158.28	0	1079
PARETO	48	.31	.47	0	1
NPARPLUS	48	37.38	155.08	0	1057
PARPLUS	48	.38	.49	0	1

Table 5.2 and 5.3 give the descriptives for the dependent variables. For the hypothesis tests of H5.1-H5.4, a p-value of 0.05 was used throughout.

Tables 5.4 and 5.5 show that hypotheses 5.1a and 5.1b are supported, so an unrestricted information architecture improves both efficiency measures.

Table 5.4 Rank statistics H5.1a-H5.1b

	Info.Arch.	N	Mean Rank	Sum of Ranks
TOTEFF	Restricted	24	28.98	695.50
	Unrestricted	24	20.02	480.50
EFF	Restricted	24	21.50	516.00
	Unrestricted	24	27.50	660.00

Table 5.5 Mann-Whitney test statistics H5.1a-H5.1b

	TOTEFF	EFF
Mann-Whitney U	180.500	216.000
Wilcoxon W	480.500	516.000
Z	-2.244	-2.110
Asymp. Sig. (2-tailed)	.025	.035

The results in tables 5.6 and 5.7 show that hypotheses 5.2a, 5.2b and 5.2d are supported, but hypothesis 5.2c falls just short of being supported. The PARPLUS measure is a binary variable, so it is a much cruder optimality measure than the NPARPLUS (the number of strictly Pareto-improving alternatives) used in the accepted hypothesis 5.2d. The overall conclusion for hypothesis 5.2 is that an unrestricted information architecture does improve (strict) Pareto optimality.

Table 5.6 Rank statistics H5.2a-H5.2d

	Info. Arch.	N	Mean Rank	Sum of Ranks
NPARETO	Restricted	24	29.79	715.00
	Unrestricted	24	19.21	461.00
PARETO	Restricted	24	21.00	504.00
	Unrestricted	24	28.00	672.00
NPARPLUS	Restricted	24	29.40	705.50
	Unrestricted	24	19.60	470.50
PARPLUS	Restricted	24	21.50	516.00
	Unrestricted	24	27.50	660.00

Table 5.7 Mann-Whitney test statistics H5.2a-H5.2d

	NPARETO	PARETO	NPARPLUS	PARPLUS
Mann-Whitney U	161.000	204.000	170.500	216.000
Wilcoxon W	461.000	504.000	470.500	516.000
Z	-2.661	-2.157	-2.491	-1.770
Asymp. Sig. (2-tailed)	.008	.031	.013	.077

Hypotheses 5.3a and 5.3b are both not supported (see tables 5.8 and 5.9), meaning that auctioning over more rounds does not significantly improve either measure of winner efficiency. This was somewhat surprising and will be further discussed in the analysis of the interaction effect.

Table 5.8 Rank statistics H5.3a-H5.3b

	Rounds	N	Mean Rank	Sum of Ranks
TOTEFF	2	24	27.27	654.50
	4	24	21.73	521.50
EFF	2	24	23.50	564.00
	4	24	25.50	612.00

Table 5.9 Mann-Whitney test statistics H5.3a-H5.3b

	TOTEFF	EFF
Mann-Whitney U	221.500	264.000
Wilcoxon W	521.500	564.000
Z	-1.388	-.703
Asymp. Sig. (2-tailed)	.165	.482

Tables 5.10 and 5.11 show that the fourth hypothesis is not supported for the PARETO and PARPLUS variables (hypotheses 5.4a and 5.4c), but when looking at the more refined optimality measure of the number of (strictly) Pareto-improving bids (NPARETO and NPARPLUS), hypotheses 5.4b and 5.4d are supported, meaning that auctioning over more rounds (weakly) increases Pareto optimality. As an aside, in conjuction with the rejection of hypotheses 5.3a and 5.3b, this result shows that the distinction between winner efficiency and Pareto optimality is not merely of theoretical importance, but that they are indeed empirically distinct as the influence of the number of rounds on both is different.

Table 5.10 Rank statistics H5.4a-H5.4d

	Rounds	N	Mean Rank	Sum of Ranks
NPARETO	2	24	29.46	707.00
	4	24	19.54	469.00
PARETO	2	24	22.00	528.00
	4	24	27.00	648.00
NPARPLUS	2	24	29.42	706.00
	4	24	19.58	470.00
PARPLUS	2	24	21.50	516.00
	4	24	27.50	660.00

Table 5.11 Mann-Whitney test statistics H5.4a-H5.4d

	NPARETO	PARETO	NPARPLUS	PARPLUS
Mann-Whitney U	169.000	228.000	170.000	216.000
Wilcoxon W	469.000	528.000	470.000	516.000
Z	-2.493	-1.541	-2.501	-1.770
Asymp. Sig. (2-tailed)	.013	.123	.012	.077

When the results are analyzed holding either the number of rounds or the information architecture constant, it shows the presence of strong interaction effects. Tables 5.12-5.15 show that the unrestricted information architecture significantly increases efficiency compared to the restricted information architecture only in the 2-round case. In the 4-round case, the two information architectures yield similar results for efficiency. The results for Pareto-optimality are similar (tables 5.16-5.19): the unrestricted information architecture only improves optimality measures in the 2-round case.

Table 5.12 Rank statistics info.arch.- efficiency (2 round case)

	Info. Arch.	N	Mean Rank	Sum of Ranks
TOTEFF	Restricted	12	15.83	190.00
	Unrestricted	12	9.17	110.00
EFF	Restricted	12	10.50	126.00
	Unrestricted	12	14.50	174.00

Table 5.13 Mann-Whitney test statistics info.arch.-efficiency (2 round case)

	TOTEFF	EFF
Mann-Whitney U	32.000	48.000
Wilcoxon W	110.000	126.000
Z	-2.341	-2.145
Asymp. Sig. (2-tailed)	.019	.032

Table 5.14 Rank statistics info.arch.-efficiency (4 round case)

	Info.Arch.	N	Mean Rank	Sum of Ranks
TOTEFF	Restricted	12	13.79	165.50
	Unrestricted	12	11.21	134.50
EFF	Restricted	12	11.50	138.00
	Unrestricted	12	13.50	162.00

Table 5.15 Mann-Whitney test statistics info.arch.-efficiency (4 round case)

	TOTEFF	EFF
Mann-Whitney U	56.500	60.000
Wilcoxon W	134.500	138.000
Z	-.910	-.923
Asymp. Sig. (2-tailed)	.363	.356

Table 5.16 Rank statistics info.arch.-optimality (2 round case)

	Info. Arch.	N	Mean Rank	Sum of Ranks
NPARETO	Restricted	12	16.38	196.50
	Unrestricted	12	8.63	103.50
PARETO	Restricted	12	10.00	120.00
	Unrestricted	12	15.00	180.00
NPARPLUS	Restricted	12	16.54	198.50
	Unrestricted	12	8.46	101.50
PARPLUS	Restricted	12	9.50	114.00
	Unrestricted	12	15.50	186.00

Table 5.17 Mann-Whitney test statistics info.arch.-optimality (2 round case)

	NPARETO	PARETO	NPARPLUS	PARPLUS
Mann-Whitney U	25.500	42.000	23.500	36.000
Wilcoxon W	103.500	120.000	101.500	114.000
Z	-2.698	-2.460	-2.825	-2.769
Asymp. Sig. (2-tailed)	.007	.014	.005	.006

Table 5.18 Rank statistics info.arch.-optimality (4 round case)

	Info. Arch.	N	Mean Rank	Sum of Ranks
NPARETO	Restricted	12	13.58	163.00
	Unrestricted	12	11.42	137.00
PARETO	Restricted	12	11.50	138.00
	Unrestricted	12	13.50	162.00
NPARPLUS	Restricted	12	12.83	154.00
	Unrestricted	12	12.17	146.00
PARPLUS	Restricted	12	12.50	150.00
	Unrestricted	12	12.50	150.00

Table 5.19 Mann-Whitney test statistics info.arch.-optimality (4 round case)

	NPARETO	PARETO	NPARPLUS	PARPLUS
Mann-Whitney U	59.000	60.000	68.000	72.000
Wilcoxon W	137.000	138.000	146.000	150.000
Z	-.780	-.811	-.247	.000
Asymp. Sig. (2-tailed)	.435	.418	.805	1.000

The overall effect on winner efficiency of increasing the number of rounds was not significant, but if we hold the information architecture constant, a slightly different picture emerges.

Under a restricted information architecture (see tables 5.20-5.21), auctioning more rounds decreases the distance to the overall efficient bid (TOTEFF), although the effect on the cruder EFF-measure remains insignificant. Under an unrestricted information architecture (see tables 5.22-5.23), auctioning over more rounds has no effect on either efficiency measure. Overall, these results imply that the number of rounds has an effect on efficiency, but the effect is weak at best.

Table 5.20 Rank statistics rounds-efficiency (restricted info.arch. case)

	Rounds	N	Mean Rank	Sum of Ranks
TOTEFF	2	12	15.42	185.00
	4	12	9.58	115.00
EFF	2	12	11.50	138.00
	4	12	13.50	162.00

Table 5.21 Mann-Whitney test statistics rounds-efficiency (restricted info.arch. case)

	TOTEFF	EFF
Mann-Whitney U	37.000	60.000
Wilcoxon W	115.000	138.000
Z	-2.040	-1.446
Asymp. Sig. (2-tailed)	.041	.148

Table 5.22 Rank statistics rounds-efficiency (unrestricted info.arch. case)

	Rounds	N	Mean Rank	Sum of Ranks
TOTEFF	2	12	12.88	154.50
	4	12	12.13	145.50
EFF	2	12	12.50	150.00
	4	12	12.50	150.00

Table 5.23 Mann-Whitney test statistics rounds-efficiency (unrestricted info.arch. case)

	TOTEFF	EFF
Mann-Whitney U	67.500	72.000
Wilcoxon W	145.500	150.000
Z	-.267	.000
Asymp. Sig. (2-tailed)	.790	1.000

With respect to the influence of the number of rounds on optimality, tables 5.24-5.27 again show an interaction effect: the increases in optimality are significant under a restricted information architecture, but non-significant under an unrestricted information architecture.

Table 5.24 Rank statistics rounds-optimality (restricted info.arch.)

	Rounds	N	Mean Rank	Sum of Ranks
NPARETO	2	12	17.08	205.00
	4	12	7.92	95.00
PARETO	2	12	10.50	126.00
	4	12	14.50	174.00
NPARPLUS	2	12	17.08	205.00
	4	12	7.92	95.00
PARPLUS	2	12	9.50	114.00
	4	12	15.50	186.00

Table 5.25 Mann-Whitney test statistics rounds-optimality (restricted info.arch.)

	NPARETO	PARETO	NPARPLUS	PARPLUS
Mann-Whitney U	17.000	48.000	17.000	36.000
Wilcoxon W	95.000	126.000	95.000	114.000
Z	-3.185	-2.145	-3.202	-2.769
Asymp. Sig. (2-tailed)	.001	.032	.001	.006

Table 5.26 Rank statistics rounds-optimality (unrestricted info.arch.)

	Rounds	N	Mean Rank	Sum of Ranks
NPARETO	2	12	12.96	155.50
	4	12	12.04	144.50
PARETO	2	12	12.00	144.00
	4	12	13.00	156.00
NPARPLUS	2	12	12.67	152.00
	4	12	12.33	148.00
PARPLUS	2	12	12.50	150.00
	4	12	12.50	150.00

Table 5.27 Mann-Whitney test statistics rounds-optimality (unrestricted info.arch.)

	NPARETO	PARETO	NPARPLUS	PARPLUS
Mann-Whitney U	66.500	66.000	70.000	72.000
Wilcoxon W	144.500	144.000	148.000	150.000
Z	-.334	-.401	-.124	.000
Asymp. Sig. (2-tailed)	.738	.688	.902	1.000

Additional analysis through t-tests for bidder profit under the experimental conditions shows that although bidder profit tends to decrease slightly when auctioning over more rounds or under an unrestricted information architecture, these differences are not significant. This implies that the additional gains to the bid taker (as indicated by lower TOTEFF measures) are not at the expense of the bidders. In other words, there is real value being created.

5.7 Discussion and conclusions

This chapter analyzed a new market institution, the multidimensional auction. It highlighted in particular one ICT-related design issue, namely the information architecture of the market. Laboratory experiments were carried out to test for the effects of information architecture as well as the number of bidding rounds on two market performance measures, winner efficiency and optimality. Results show that an unrestricted information architecture (i.e. more information revealed about the state of competition and the bid taker's preferences) increases the optimality and winner efficiency of the multidimensional auction. Auctioning over 4 rounds instead of 2 improves the optimality of the auction, but has no overall effect on winner efficiency. These are by and large conform expectations, although a stronger effect of the number of rounds was expected, particularly regarding winner efficiency. Perhaps the increase from 2 to 4 four rounds was too small to yield significant improvements, but this is something that future experiments over more rounds will have to resolve.

What is somewhat surprising however, is that the effects of information architecture and auctioning rounds are highly dependent on each other: the presence of strong interaction effects shows that an increase of one experimental variable only improves market performance if the other experimental variable is low. In other words, auctioning more rounds can act as a partial substitute for more feedback in a given round and vice versa.

A possible explanation for this effect may be found in the role of information in the decision processes of the individual bidders. As Koppius and van Heck (2001) argued, the revision of bids by an individual bidder from round to round seems to be consistent with the general belief-adjustment model proposed by Hogarth and Einhorn (1992). An important feature of the belief-adjustment model is that the degree of adjustment is not just dependent on whether the evidence is positive or negative, but also dependent on the previous belief against which it is evaluated. For example, information that is negative compared to the held belief will cause minor belief-adjustment if that belief is already fairly close to the (negative) evidence. If the same negative information is evaluated against a strongly held belief, belief-adjustment will be much stronger ('the harder they come, the harder

they fall'). In the negative information case, the adjustment is proportional to the current position, whereas in the positive information case, it is inversely proportional to the current position (Hogarth and Einhorn, 1992).
Most subjects indicated after the experiment that they primarily thought of the bidding process as a search for the bid taker's optimum, which is quite different from a single-dimensional auction where the emphasis is on beating the competition. So, if we view the bidding process in a multidimensional auction as a search for the bid taker's optimum, the bidder's belief corresponds to where he thinks the bid taker's optimum is located and he is assumed to bid accordingly. Information at the end of the round can then be interpreted as positive if the highest bid is close (in the bid space) to the bidder's bid in that round and negative if the highest bid is located far from the bidder's bid in that round. Some bidders perceived this information role of bids quite well when they commented that it was a disadvantage to be the highest bidder in the penultimate round, particularly in the restricted information architecture, because then you had less information than the other bidders to go on in revising your bid.
As bids converge during the auction towards where bidders *initially* think the optimum is, the information that those bids reveal at the end of each round becomes less informative, because the revealed information is already fairly close to the position held. In other words, there will be only minor belief-revision (i.e. updating of the assumed bid taker's optimum) and bidding is likely to remain in that region of the bid space, with auction performance remaining stable at a sub-optimal level.

Although the discussion above pertains to multidimensional auctions, this result yields an interesting speculative interpretation of what it takes to make a market in general perform well in terms of efficiency and optimality. A less restricted information architecture increases the amount of information about competitors' private information and bid taker preferences that is revealed during the market process. The same line of reasoning applies to an increase in the number of rounds: auctioning more rounds gradually reveals more information about bid taker's preferences and the state of competition. The interaction effect between those two implies strongly diminishing returns to revealing additional information, either through a less restricted information architecture or through revealing information over more rounds. The reason is that the additional information, despite being credible and correct, simply is not effective in changing bidding behavior. Bidders' belief that the current highest bid is correct may simply be too strong to be swayed by any further information. This implies that market performance will then remain at a sub-optimal level. In other words, there seems to be a phenomenon of *information saturation* at work in the market: beyond a certain point, more information does not improve market performance any further.

CHAPTER 6 - SYNTHESIS: A CONCEPTUAL MODEL OF ELECTRONIC MARKETS

6.1 Introduction

The purpose of this chapter is to synthesize the findings of the previous chapters into a model of electronic markets. Such a model, preliminary as it may be, will hopefully contribute to a more detailed understanding of market processes and their outcomes and how ICT influences them. So in a way, this is a model of markets in general, but with an added emphasis on the role of ICT. In order to give this chapter the proper context and focus, an important level-of-analysis distinction is emphasized between a market theory and a theory of the market (Lie, 1997). A market theory uses the concept of the market to theorize about social and economic life, such as the transitions to a market economy (Nee, 1989), the market-hierarchies debate (Williamson, 1975, 1985) and economic theories about marriage and the family (Becker, 1976, 1981). A theory of the market theorizes about market processes, i.e. how and why a market functions the way it does. My focus is on the latter category of theories. This does not mean that market theories are not important or that ICT could not be a relevant factor in such theories (see for instance Malone, Yates and Benjamin (1987) and the subsequent debate regarding a shift from electronic hierarchies to electronic markets), but simply that it is outside the scope of this dissertation. The goal of the model developed here is to look inside the black box of markets, i.e. to explain how and why which transactions arise. This differentiates this model from for instance models in neo-institutional economics, particularly transaction cost economics, which compare markets to other governance mechanisms. It is also different from models in strategic management and marketing (both usually derived from the industrial organization literature) that deal with the definition of a market, which is commonly interpreted as the definition of the *boundaries* of the market. The model developed here complements those models, because it assumes that the choice for the governance mechanism of the market has been made and that the market boundaries have been defined.

The starting point of the model is that markets are most properly viewed as a dynamic social structure. This view emphasizes that markets should be viewed as a process, not just an outcome and that the market process occurs among distinct social entities instead of identical, atomized actors (for a more detailed overview of how this view differs from the way the market has been viewed in most economic theory, sociology and other literatures, please refer to the appendix at the end of this chapter). This emphasis is echoed in the specific definition of a market adopted at the beginning of this dissertation: markets are social institutions that facilitate exchange by means of competition (Coase, 1988; Weber, 1978 [1922]; Swedberg, 1994). Although Coase (1988) initially defines markets as "…institutions that exist to facilitate exchange" (p.7), i.e. without the adjective 'social', on the next page, he states: "And when economists speak of market structure, …, the influence of the social institutions which facilitate exchange [is] completely ignored." (Coase, 1988, p.8). Therefore the definition explicitly adds the word 'social', to emphasize the fact that all market transactions are embedded in a social structure among traders (Baker, 1984; Granovetter, 1985). Social status among trading parties influences exchange processes (Podolny, 1993); it matters to people who the other party in a transaction is, beyond mere reputation effects (DiMaggio and Louch, 1998).

The addition of "…by means of competition." is due to Swedberg (1994), based on the work of Max Weber (1978 [1922]). This addition is important because not only is competition the element that distinguishes markets from other allocation mechanisms or processes (Polanyi, 1957), but more importantly it is competition that explicitly embodies the dynamic social structure view: competition occurs among social entities as they react to each other's actions.

6.2 A conceptual model of electronic markets

The conceptual model of electronic markets developed in this section is a description of the phases in the exchange process that occur until the trading parties agree upon the terms of the trade. Although the model does not explicitly include the phases of the exchange process that occur post-agreement (for instance logistics and payment and settlement, see Kambil and van Heck (1998)), implicitly they are taken into account in the trader's decision processes regarding the terms of the trade. The model (see Figure 6.1 for an overview) is described starting from the market outcome and performance and then work back up the model through the information exchange processes and the information architecture of the market, eventually arriving at the influence of ICT.

Paragraph 1.2 defined market processes as the processes of information exchange that occur in the market and market outcome as the set of transactions that arises as a result of this market process.

Figure 6.1 illustrates this for a market consisting of 3 buyers (B1 – B3), 4 sellers (S1 – S4) and 2 intermediaries (I1 – I2). In line with the focus on the information architecture and to prevent clutter, the other market process determinants are omitted from fig. 6.1, as is the direct effect of ICT on the information exchange processes (see also fig. 1.2).

Market outcome and performance and information exchange processes

The network of dotted lines indicates the information exchange processes among traders, such as the exchange of bids and asks. This process continues until it converges on agreement over the terms of the trade, i.e. a transaction, or until a trader stops communicating, effectively leaving the market. Based on the market rules regarding allocation and transaction validity, the process will eventually result in some market outcome, i.e. transactions. Performance criteria regarding market outcome and accompanying market process then determine market performance (see also paragraph 1.1). We thus have the following two propositions:

Proposition 6.1: The information exchange processes among traders determine market outcome.

Proposition 6.2: Market process and market outcome together determine market performance

Information exchange processes and the market information set

To see why information exchange determines market outcome, we have to look more closely at the decision processes of a trader. It is assumed that each trader arrives at the market with an initial willingness-to-pay (WTP) in the case of the buyer and an initial willingness-to-accept (WTA) in the case of the seller. These reflect each trader's unique preference to buy or sell a certain product.

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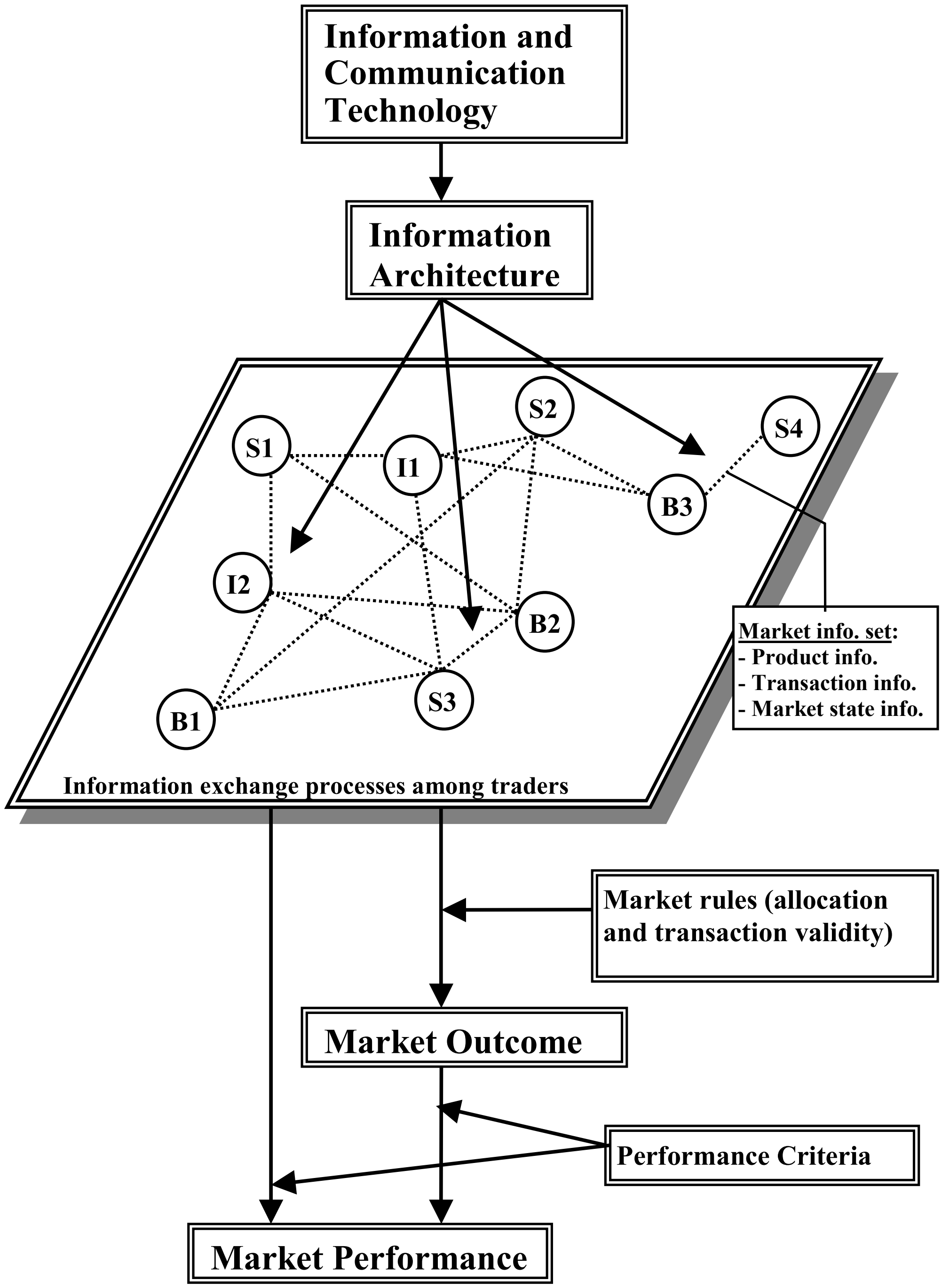

Figure 6.1 A conceptual model of electronic markets

Trade is possible only if a buyer's WTP exceeds a seller's WTA. Therefore, the first step in trading is finding another trader with which a trade is potentially feasible, i.e. the search phase in Kambil and Van Heck (1998). A main function of exchanging information in a market is to locate such traders. This search process can take many forms, for instance publicly announcing the auction of a product or communicating one-on-one with other traders.

This is not the only function of information exchange however. Although traders arrive at the market with an initial set of preferences (his WTA or WTP), there is usually considerable uncertainty surrounding the trading conditions. This is reflected in the possibility that a trader may update his preferences once new information arrives that reduces this uncertainty. For instance, a buyer (seller) may find out during the market process that the product he wants to buy (sell) is much more in demand than he initially thought. This implies that the buyer may need to adjust his initial WTP upwards if he wants to acquire the product (which could lead to the winners' curse (Capen, Clapp and Campbell, 1971; Kagel and Levin, 1986) or that the seller may adjust his WTA upwards to maximize his profit.
A different example involves a buyer that finds out that the product he was initially looking for is unavailable. Assuming the buyer does not want to leave the market empty-handed, he will have to settle for a different product that is available. If he has not exhaustively specified his WTP for all (combinations of) alternatives in advance, he may need to construct his WTP on the spot if a satisfying product is offered for trade. More generally, the initial WTA and WTP of a trader are not fixed, but may be updated during the market process based on the information revealed. Other factors may play a role in this updating process as well. For instance, Malhotra and Murnighan (2000) show that substantial overbidding in the Chicago cow auctions cannot be explained by a rational choice model, but can by processes of escalation of commitment and competitive arousal among bidders. It is beyond the scope of this dissertation to fully discuss how trader's individual WTA or WTP change based on new information[9], but it will look more closely at what type of information may cause belief updating.

[9] However, the empirical validity of the belief-adjustment model (Hogarth and Einhorn, 1992) in a wide variety of contexts suggests that this is a good starting point for an investigation of such WTA/WTP-updating.

This dissertation distinguishes between at least three types of information that are exchanged among traders and therefore can cause belief updating. These three categories combined are called the *market information set*, and it consists of product information, market process information and market state information.
Product information (the focus of chapter 3 and also playing a role in chapter 4) consists of descriptive information about the product that is to be traded. It helps traders to reduce uncertainty regarding the quality of the product. *Market process information* (the focus of chapter 5) is transaction-specific information and can include information items such as the highest bid, rejected bids or trader identity. Although information items such as seller identity can be used to reduce product quality uncertainty by functioning as a substitute (e.g. reputation) for missing product information, the main function of this category of market information is to influence the competition process and the resulting WTA/WTP updating. The third category is *market state information* (see chapter 4), which is defined as public, non-transaction signals that influence trading behavior. Such signals give information about the overall state of the market, regardless of the conditions surrounding any individual transaction. Examples are the number of traders present in the market or the sound level in an open outcry market (Coval and Shumway, 2000). This category of information again influences the competition process, possibly resulting in WTA/WTP updating by traders.
It is important to note that these different categories of the market information set serve different purposes and are therefore likely to have different effects on trading behavior (as the KOA study in chapter 4 showed). Aggregating information into a single dimension obscures the fact that information itself is a multidimensional construct[10] and therefore should be treated as such. One cannot speak of the effects of 'more' information on market performance if such effects depend on which *category* of information is provided more. In short, we have the following proposition:

[10] Milgrom and Weber (1982), in their seminal work on auction theory, were aware of this too: "To represent a bidder's information by a single, real-valued signal is to make two substantive assumptions. Not only must his signal be a sufficient statistic for all of the information he possesses concerning the value of the object to him, it must also adequately summarize his information concerning the signals received by the other bidders." (Milgrom and Weber, 1982, p.1097, footnote 14). They go on to note: "The derivation of such a statistic from several separate pieces of information is in general a difficult task…". I therefore think that disaggregating a bidder's information may be a fruitful approach.

Proposition 6.3: Traders exchange information from the market information set, which consists of at least three distinct categories of information: product information, market process information and market state information. Each category affects trading behavior differently.

The market information set and information architecture

The market information set describes the information that potentially could be exchanged. In practice, there is imperfect information: certain types of information are simply unavailable, either by default (such as smell in an electronic market) or by choice of the market designer. Informally stated, the information architecture of the market describes which information is actually available to which traders in the market under investigation. It consists of general rules and specific rules. General rules are descriptive of certain groups of traders overall and are therefore invariant across trades. The fact that the external KOA-buyers in chapter 4 lack information regarding the market state that auction hall buyers do have is an example of a general rule. Specific rules are related to specific trades. They can specify that, like in the experiments in chapter 5, for some trades only the highest bid will be revealed, whereas for other trades all bids will be revealed. These two types of rules govern the actual processes of information exchange among traders:

Proposition 6.4: The information architecture of the market influences the information exchange processes among traders by specifying which elements of the market information set are, or when and how they become available, to whom during the market process.

Information architecture and ICT

Having thus defined the role of the information exchange processes and information architecture in determining market outcome, we can now turn to the role of ICT. ICT is defined as “The infrastructure that makes it possible to store, search, retrieve, copy, filter, manipulate, view, transmit and receive information.” (Shapiro and Varian 1999, p.8). One important aspect of this definition is that it is much broader than just electronic forms of communication. Put in a different way, the definition says that as soon as information is actively involved, there is some form of ICT associated with it (the infrastructure). The implication is that it is not correct to talk about markets in terms of *with* or *without* ICT, but rather that the proper view is that of a market before and after a *change* in ICT. This leads to a focus on what the change in ICT involves, i.e. which features of the ICT do actually change? (Griffith and Northcraft, 1994). A partial list of features that are involved in an ICT (adapted from Daft and Lengel (1986), Culnan and Markus (1987), Huber (1990) and Nass and Mason (1990)) is: media richness, location specificity (the need to be in a specific place in order to communicate), synchronicity of communication, speed of communication, addressing, data storage and archival functions, access control, anonymity and cost.

This features-based approach (Griffith, 1999) is illustrated with a few simple examples. A regular phone and a mobile phone differ primarily in location specificity, whereas the main difference between email and a letter is in the speed of communication and in cost. Likewise, the difference between an extranet and the regular Internet is only in access control, since they both use the same underlying TCP/IP technology. Most electronic ICTs allow for addressing communication to a certain space (such as a bulletin board) for all to see, instead of addressing it to a person. The chief difference between email and chat-type ICTs such as IRC (Internet Relay Chat), ICQ and AOL Messenger is in the synchronicity of the communication.

Just as information is a multidimensional concept, in which the different dimensions can have different effects, the discussion above illustrates that a similar case can be made for ICT: different features are likely to cause different effects. With respect to the research in this dissertation, changes in the following ICT features are distinguished:

- location specificity
- media richness
- data storage and archival functions
- access control.

In the electronic markets literature, the effect of ICT has been mainly conceptualized as a reduction in transaction costs (Bakos, 1991, 1997) or somewhat broader, a reduction in coordination costs (Butler at al., 1997). In a more abstract sense, this reduction mainly occurs because ICT reduces the location specificity of market processes: in an electronic market one does not need to assemble in the same physical space to conduct market transactions. This in turn reduces travel costs and entry barriers to markets and makes it easier to search across markets (augmented by improved archival functions that make retrieving market information easier), thus resulting in reduced transaction/coordination costs. The effects of reduced location specificity were one of the main drivers behind the results in chapter 4.

A change in ICT also entails a change in the media richness of the communication channel. Media richness is the capacity of a medium for processing equivocal information, as determined by its capability for instant feedback, transmitting multiple cues, use of natural language and personal focus (Daft and Lengel, 1986). The results in chapter 3 can essentially be attributed to the reduced media richness of the electronic communication channel: compared to the physical 'communication' of the flowers, bidders now lacked cues regarding color and freshness. This increased the equivocality of the message, thereby increasing the uncertainty over its interpretation, resulting in the price drop that was observed.

Changes in ICT also entail changes in data storage and archival functions. The KOA-system in chapter 4 stored data for all 10 auction-clocks, thus allowing buyers to switch effortlessly from one auction to another. The auction software used for the experiments in chapter 5 kept track of each bidder's bids in previous rounds, thus facilitating their decision processes.

Certain ICTs also allow for various forms of access control: who gets access to what information. An unintended example of this occurred in the KOA-study, where internal KOA-buyers used the video security cameras to gain additional information about the auction process. The restrictions placed on the information revealed to bidders during the experiments in chapter 5 are also a form of access control: although full information on all received bids was available for all auctions throughout the whole experiment, only for half of the auctions did bidders have access to that information. In those experiments all bidders had the same access, but access control could also be manipulated such that for instance only one bidder has access to all submitted bids (an 'insider'), whereas the other bidders only see the highest bid.

The discussion above, while certainly not exhaustive, shows that reduced location specificity (and the resulting lower transaction costs) is only a small part of the total effect that ICT can have on market processes. Several other effects exist and they all deal with the different types of information that are becoming more (or less) available in an electronic market. In other words, they deal with changes in the information architecture of the market. This leads to the final proposition:

Proposition 6.5: ICT changes the information architecture of the market through changes in media richness, data storage and archival functions and access control.

Viewing the model in a different way, ICT and market performance are linked through the following five steps:

1. A change in ICT changes the information architecture of the market. (P6.5)
2. The information architecture determines which elements of the market information set are (or become) available to traders during the market process. (P6.4)
3. The market information set, as determined by the information architecture, affects the information exchange processes among traders (P6.3)
4. The information exchange processes among traders result in a set of transactions, i.e. market outcome, based on the market rules regarding allocation and transaction validity. (P6.2)
5. Market process and market outcome determine market performance, based on the specific performance criteria. (P6.1)

6.3 The first validity check on the model

The conceptual model in the previous paragraph was developed inductively by analytically generalizing from the causal relationships found in the individual studies to the more abstract level of electronic markets in general. Results were generalized over a number of dimensions:

- from Dutch auctions to markets
- from multidimensional auctions to markets
- from two specific information architectures to information architecture in general
- from screen auctioning to ICT
- from KOA to ICT
- from Anthurium flowers to generic products
- from a lab setting to a general setting

Such a list raises questions about the validity of the model. This paragraph performs the first validity check by briefly reframing the three empirical studies of chapters 3-5 in terms of the five steps at the end of the previous paragraph. This should yield some provisional evidence of the internal validity of the model, i.e. that the causal inferences are correct. It should also demonstrate that the model, despite its generality, can indeed be fruitfully used to analyze specific electronic markets, as the first step towards establishing external validity.

Screen auctioning

1. There was a change in ICT, with the new ICT (screen auctioning) being lower in media richness due to electronic product representation instead of physical product representation.
2. This reduced media richness of the electronic product representation entailed that certain cues regarding product quality such as stiffness of the stem and color (i.e. both elements of the market information set) are no longer available to bidders.
3. As a consequence, bidders faced greater uncertainty regarding flower quality in their bidding.
4. Bidders accounted for this increased uncertainty by bidding lower prices on average.
5. Market performance in terms of market transparency decreased. Because of this, most likely not all the available information was reflected in prices, implying a decrease in informational efficiency.

KOA

1. There was a change in ICT, with the new ICT (KOA) entailing changes in data storage and archival functions (KOA-buyers vs. hall-buyers) as well as access control (hall-buyers and internal KOA-buyers vs. external KOA) and media richness. The direct ICT effects of reduced transaction costs are omitted in this paragraph.
2. Both internal and external KOA-buyers faced lower search costs than hall-buyers, due to improved data storage and retrieval, making it easier to switch among clocks. All bidders were faced with electronic product representation because the Anthuriums analyzed were already being screen-auctioned. However, the external KOA-bidders faced lower media richness than internal KOA-buyers and hall-buyers because they did not

have the option to go through the warehouse in the morning to inspect the flowers, thus potentially missing product cues such as color and stem stiffness (product quality information). The external KOA-buyers did not know the number of bidders present in the auction hall (market state information), something which the hall-buyers knew, as did the internal KOA-buyers because of the security camera system (a type of access control, albeit an unforeseen effect).

3. External KOA-buyers faced greater uncertainty than other bidders regarding flower quality as well as regarding the number of bidders present. Both internal and external KOA-buyers had lower switching costs than hall-buyers due to increased market transparency.
4. The lower switching costs/increased market transparency for internal KOA-buyers led them to bid lower prices on average than external KOA-buyers and hall-buyers. The combined effect of increased quality uncertainty, increased market state uncertainty and lower switching costs for the external KOA-buyers was neutral: they paid the same prices as hall-buyers.
5. Market performance in terms of market transparency increased. Because of this, most likely more of the available information was reflected in prices, leading to increased informational efficiency.

Multidimensional auctions

1. A change in the access control aspects of ICT changed the information architecture of the auction from restricted to unrestricted in the experiment.
2. Instead of seeing only the highest bid at the end of each round (the restricted information architecture), in the unrestricted information architecture, bidders now saw all the bids that were submitted, ranked, and including the relative score based on the auctioneer's scoring rule.
3. Through the increased information about both the state of competition as well as bid taker's preferences, bidders had more information about the direction in which to improve their bid in order to win the auction.
4. This led to the winning bids in the unrestricted information architecture being significantly different from winning bids in identical auctions under a restricted information architecture.

5. Market performance improved significantly in the unrestricted information architecture, as measured by winner efficiency and Pareto optimality.

Although by no means a complete and thorough test of the validity of the model, the analysis above suggests that the model passes some basic criteria for usefulness: the proposed causal inferences in the model concur with those in the three empirical studies and the model is general enough to encompass markets in both a field and a lab setting, yet the steps in the model are specific enough to highlight the 'differences that make a difference'.

6.4 Conclusion

This chapter developed a conceptual model of electronic markets, integrating various concepts from the previous chapter, centered on the notion of the information architecture of the market. It outlined how the information exchange processes lead to a market outcome and how these processes are affected by the information architecture. It then discussed how a change in ICT can affect market processes and in particular how many of these effects can be viewed as a change in the information architecture of the market. As the first check on the validity of the model, the three empirical studies were reframed in terms of the general model. This analysis suggests that the model has a degree of usefulness and parsimony that warrants further application in future studies, which should establish the degree of external validity of the model.

CHAPTER 7 : CONCLUSIONS AND FURTHER RESEARCH

This chapter concludes my thesis by summarizing in the first paragraph the main findings from my studies. Paragraph 2 describes the limitations of the research, and in the third paragraph some implications and areas for future research are outlined.

7.1 Thesis findings and contribution

As this thesis comprises of three separate studies within the methodological framework of multi-method research, this paragraph first discusses the findings for each detailed research question from paragraph 1.2 that motivated the respective study, before discussing the overall findings.

The first study dealt the effects of one category of market information, product quality information, in the form of the following research question:

(DRQ1): How does reduced product quality information affect market process, market outcome and market performance in an auction?

This question was investigated in a case study at a large Dutch flower auction. The auction had introduced a new auction system in which participants lacked certain informational cues for product quality, such as flower color and flower freshness, which led to greater product quality uncertainty. Statistical analysis of transaction data before and after the introduction of this new auction system revealed that the increased product quality uncertainty led bidders to bid about 2% lower on average. Screen auctioning as such is not a fully electronic market as bidders still physically gather in the auction hall. However, it does represent an intermediate step towards such an electronic market as in both cases electronic product representation is involved. This study shows that one of the consequences of switching to an electronic market may be reduced availability of product quality information, which in turn has a negative impact on prices.

The second study dealt with the effects of another category of market information, market state information, as well as the consequences of reduced search and switching costs, by investigating the following research question:

(DRQ2): How do reduced search and switching costs and reduced market state information affect market process, market outcome and market performance in an auction?

This was studied in another case study at the same flower auction as the first research question. The auction allowed bidders to bid electronically from their home or office instead of being physically present in the auction hall (the KOA system). The electronic bidders bid in the exact same auctions at the same time as the bidders in the auction hall, so this allows for a detailed comparison between online bidders and offline bidders. While still not being a fully electronic market, KOA is a step beyond screen auctioning towards a fully electronic market, because now (in addition to electronic product representation) there are also electronic bidders present in the market.
Electronic bidding brings a reduction in search and switching costs for the electronic bidders, but at the same time they lacked information about the state of the market such as the number of bidders present in the auction hall. A statistical comparison of electronic bidders and bidders in the auction hall revealed that electronic bidders paid lower prices on average, as predicted by Bakos (1991). Subsequent investigation showed that this reduced price hypothesis only held for the electronic bidders who had their offices on the auction hall complex (internal bidders). Electronic bidders that had their offices elsewhere (external bidders) paid the same prices as the bidders in the auction hall. One explanation for this somewhat surprising finding is that there is a selection bias at work that cannot be controlled for: internal and external bidders may differ in their bidding strategies or their general purchasing strategies (orderbook buyers vs. cherry-pickers). Another explanation is that the internal bidders, through the security camera system that they had access to, had non-transaction information about the state of the market that the external bidders lacked. In particular, the external bidders lacked accurate information about the number of bidders present, which increased uncertainty may have led them to pay a premium in their bids compared to the internal bidders. More generally speaking, reduced market state information increases bidder uncertainty regarding the optimal bid level, given his preferences.

This type of uncertainty may cause bidders to make conservative assumptions regarding these unknown variables, with conservative in the sense that it minimizes their chance of not receiving the product they want to acquire. This results in higher prices. In addition to showing that reduced transaction costs in electronic markets do indeed lead to lower prices, this second study highlighted the importance of market state information. A change in ICT may change the market state information available to participants in an electronic market and a preliminary hypothesis is that a reduction of market state information leads to higher prices.

When moving from a market towards a fully electronic market, the physical components of the market processes gradually disappear as they are substituted by informational components. This implies that especially for electronic markets, the emphasis on the information exchange processes in the market becomes stronger and stronger, simply because that is all there is in an electronic market. This focus on information exchange processes in the first two studies led to the introduction of the concept *information architecture of the market* in the third study: the information architecture describes what type of information is, or when and how it becomes available, to whom during the market process.

Whereas the first two studies dealt with the role of ICT in automating existing market processes, in the third study a new type of ICT-enabled auction mechanism was developed, called the multidimensional auction. In a multidimensional auctions, bidders bid not only on price, but on multiple dimensions such as quality, delivery time and warranty. This is particularly relevant in a procurement setting in which the specifics of the traded object are not as fixed as in a traditional sales auction. Coupled with the concept of information architecture, this led to the third research question that investigated a third category of market information, market process information:

(DRQ3): What is the influence of a change in the information architecture of market process information on market process, outcome and performance in an electronic multidimensional auction?

This question was investigated in two laboratory experiments in which student subjects bid in a series of Web-based, multi-round multidimensional auctions under different information architectures (restricted and unrestricted) as well as varying numbers of rounds (2 and 4 rounds). The results from the experiments showed that both market performance measures, winner efficiency and Pareto optimality, increased if a less restrictive information architecture was employed or if the auction last more rounds. Both of these findings are in line with the hypothesized effects. A somewhat surprising finding was that there was a strong interaction effect between the two experimental manipulations: the unrestricted information architecture significantly increases efficiency and optimality only in the 2-round case. Similarly, increasing the number of rounds yields only significant efficiency and optimality improvements under a restricted information architecture. It seems to be that there are strongly diminishing marginal returns to information. A tentative explanation for this could be that individual bidding behavior follows the belief-adjustment model (Hogarth and Einhorn 1992). The consequence is that information, despite being credible and correct, may not always be effective in changing bidding behavior. Bidders' belief that the current highest bid is correct may simply be too strong to be swayed by any information. This implies that market performance will then remain at a sub-optimal level (Koppius and van Heck, 2001). In other words, there is a phenomenon of *information saturation* at work in the market: beyond a certain point, more information does not improve market performance any further.

A more general point of this particular study is that it emphasizes the *process* nature of markets. For instance, in much of the auction literature the length of the auction process is treated as irrelevant (but see Engelbrecht-Wiggans (1988) for an example of how it could be incorporated) and the information available to bidders is exogenous to the auction process itself (see Bergemann and Pesendorfer (2001) for a recent exception though). The experiments reported here show that, contrary to current theory, both these process-related factors have a significant influence on the auction outcome.

The synthesis of the three studies is provided in the overall research question of this dissertation, which was:

(ORQ) How does ICT influence the information architecture of the market and how does this affect electronic market process, electronic market outcome and electronic market performance?

As described above, the three empirical studies each highlight different aspects of the answer to this question. A more general and comprehensive answer to the overall research question is given in chapter 6, where the results in chapters 3-5 are theoretically generalized into a conceptual model of electronic markets. Focusing on the information exchange processes among traders in a market, a model is constructed that incorporates ICT, information architecture, market processes and market outcome. The constructs are linked through several propositions, eventually relating ICT and market outcome through the following five steps:

1. A change in ICT changes the information architecture of the market. (P6.5)
2. The information architecture determines which elements of the market information set are (or become) available to traders during the market process. (P6.4)
3. The market information set, as determined by the information architecture, affects the information exchange processes among traders (P6.3)
4. The information exchange processes among traders result in a set of transactions, i.e. market outcome, based on the market rules regarding allocation and transaction validity. (P6.2)
5. Market process and market outcome determine market performance, based on the specific performance criteria. (P6.1)

Although the model as a whole would need a comprehensive empirical test before we can accept it, each of the links among the constructs in the model has been empirically established in one or more of the studies. Furthermore, as the first check on the validity of the model, the three empirical studies were reframed in terms of the general model. That analysis suggests that the model has a degree of usefulness and parsimony that warrants further application in future studies, which lends initial credence to the model as a theory of electronic markets.

7.2 Limitations of the research

The main goal of the dissertation was: "…to show that focusing on the information exchange processes in the market and in particular the concept of information architecture is a fruitful way to analyze markets, especially when dealing with the effects that ICT has on markets." (paragraph 1.2). To achieve this goal, a multi-method approach was followed (Brewer and Hunter 1989), combining case studies followed by a laboratory experiment. Such sequential triangulation allows the findings of one study to inform the following, thus refining the research. The combination of case studies and experiments combines the main strengths of both methods: high external validity for the case study and high internal validity for the experiments. This should ensure that the concept of information architecture has greater validity than when investigated with a single method. Despite that, there are some limitations to the research.

The case studies at the flower auction were primarily quantitative, dealing with transaction data on prices. Although discussions with auction personnel and several bidders partially informed the studies, it is possible that other factors influenced bidding behavior, which could distort the results. In particular, the general purchasing strategy that bidders follow could have an influence on bidding behavior, as the discussion at the end of chapter 4 showed. Since no data was available to control for that factor, there remains a possibility of selection bias if KOA-buyers follow different purchasing strategies than the buyers in the auction hall or are different on other aspects that could influence their bidding behavior. Furthermore, the hypotheses in both studies were tested using data from a single type of flower, the Anthurium. On one hand, this is a strength of the research, because this flower was the only one for which the screen auctioning technology in chapter 3 was introduced before the KOA technology of chapter 4, which allowed me to separate methodologically the effects of product quality information from the combined effects of reduced transaction costs and reduced market state information. On the other hand, it represents a limitation, because it is possible that the results that were found are specific for Anthuriums only. Each flower has different characteristics that are important to buyers, so it is possible that my results do not generalize to other flowers or non-flower products. However, framing the results in generalized theoretical terms such as product quality information and market state information suggests that they *could* be relevant in other cases as well. Whether or not they are is subject to further empirical testing.

The experiments conducted in chapter 5 yielded conclusive evidence that information architecture matters in multidimensional auctions, but at the same time it is only a small step towards establishing the general validity of that construct as it was only tested for a specific variant of a multidimensional auction. Therefore, how much of the effect of information architecture is due to the specific nature of this multidimensional auction is open to question. In particular, the cognitive complexity of multidimensional bidding places greater emphasis on the availability of certain information and it is possible that in simpler, single-dimensional auctions, information architecture might play a smaller role. A limitation with regards to the multidimensional auction itself is that it was tested only in a particular laboratory environment, which may limit the generalizability to the variety of (multidimensional) auctions that occur in practice.

7.3 Implications and further research

The first main contribution of this dissertation is establishing information architecture as a significant factor shaping market performance. Information architecture to a large extent shapes the information exchange processes that occur in a market. Such processes are more than just descriptive labels of what happens in a market, this dissertation showed that they are in fact crucial to understanding why markets behave the way they do. Therefore an important implication of this dissertation, both for researchers and market designers, is that any analysis or design of a market will be incomplete without a thorough analysis of the information exchange processes. The concept of information architecture can provide a useful framework for such an analysis. A particularly interesting finding is the information saturation phenomenon that seems to be at work in the markets in chapter 5, which could have important implications for regulations regarding market transparency. If markets do indeed become saturated with information at a certain point, so revealing more information beyond the information saturation point does not improve market performance any further, it suggests that maximum market transparency may not be as necessary for good market performance as perhaps sometimes thought.

A second main contribution of this dissertation is to provide a more detailed look at how ICT influences markets. Most work to date on electronic markets has been done from a transaction cost perspective. This dissertation shows that ICT can have a variety of effects in addition to reduced transaction costs. Many of these other effects are related to changes in the various types of information that are available to participants in an electronic market, in other words: a change in information architecture. Therefore future work on electronic markets should augment a transaction cost analysis with an information architecture analysis.

The third main contribution of this dissertation is to provide one of the first comprehensive conceptual models of electronic markets by relating ICT, information architecture and market processes and outcome. Previous authors have looked at one or more isolated variables without relating them to an overall model of electronic markets, but additional theorizing is necessary to arrive at a coherent theory of electronic markets. The model presented in this dissertation is the first step in that direction.

Despite these contributions, much more work remains to be done. Different types of auctions need to be researched to establish more broadly the validity of the information architecture construct. Different types of information architectures need to be investigated to check their influence on winner efficiency and Pareto optimality, as well as other market performance measures such as speed of convergence or perceived fairness of the market.

More attention needs to be paid to individual bidding behavior as well. Degeratu, Rangaswamy and Wu (2000) showed that shopping behavior online is qualitatively different from traditional shopping behavior, particularly in terms of how different types of information were incorporated into the shopping decision, so it is quite likely that online bidding behavior will be different from traditional bidding behavior. The studies in chapter 3 and 4 only scratch the surface of this topic. A particularly fruitful approach would be to incorporate more results from behavioral decision theory (e.g. Anderson, 1981; Nisbett and Ross, 1980; Hogarth, 1987). A better understanding of the decision processes of traders in a market is likely to lead to a better understanding of their behavior at the aggregate level of the market.

Last, but by no means least, the concept of multidimensional auctions merits much further research. As organizations become more customer-oriented (Vervest and Dunn, 2000) and customer preferences instead of producer capabilities become the starting point for a transaction, the traditional supply chain gets turned on its head and becomes a demand web where organizations compete to fulfill the demand of the customer. Coordinating this process through a win-lose mechanism such as a one-dimensional auction is only a stopgap measure. Consumer demand is multidimensional, as should the auction be.

APPENDIX I: EXPERIMENT INSTRUCTIONS

Note: the experiment was carried out in Dutch. This is the translated version of the instructions.

In this experiment, you are the owner of a company that produces hydrochloric acid. Your customers are other chemical companies (the buyers) who need hydrochloric acid regularly for their production process. You play the role of supplier, i.e. the seller. Transactions occur through an auction mechanism, where you as seller play the role of the bidder.

Your bid consists of three elements: delivery time (t), contamination (c) and price (p), that you can enter later on the input screen. There you will also find a 'PROFIT' button. If you press that, it calculates how much profit you would make if you were to place that particular bid. Bidding itself is done by pressing the 'BID' button.

Your profit is being calculated based on the price and your internal production costs. You have in front of you a table with your own internal production costs for several combinations of delivery time and contamination (as well as the general formula that is being used for it). As you will see, for each bidder the costs rise the faster the delivery time and/or the less contamination, however, the exact costs are different for each bidder and you should keep those secret.

The auction occurs in rounds. In every round you have to place a bid. At the end of each round, you receive information about the highest bid so far and perhaps some other information, after which you can place a new bid. The winner is the one who at the end of the last round has the highest bid overall. This is the highest bid from all rounds so far, so not necessarily the highest bid in the last round.

The highest bid is determined by the scoring rule of the auctioneer (the buyer) that trades price, contaminations and delivery time off against each other. In each auction, the buyer/auctioneer makes a different tradeoff, which causes the optimal bid to be at a different combination of variables each time. The exact scoring rule that is being used, is kept secret. Each auction represents a new buyer with a new scoring rule, which changes from auction to auction, but remains the same for each round within a specific auction.

When the auction ends, the winner earns the profit he made on his bid (the losing bidders earn nothing). At the end of the experiment, each participant will receive *double* his total earnings in guilders, in addition to a participation fee of 10 guilders (approx. US$ 4.00).

Good luck!

APPENDIX II: DATASET EXPERIMENTS

The table on the next page lists the results dataset for the two experiments. The variables in the columns have the following meaning:

- *ExpNo* = the experiment number, (I) original, (II) replication
- *Rounds* = the number of rounds in the auction
- *I.A.* = information architecture, 1 = restricted, 11 = unrestricted
- *UserID* = ID of the winning bidder
- *Round* = the round in which the winning bid was made
- *Profit* = the profit that the wining bidder made
- *Score* = the absolute score of the winning bid (all scores were negative due to the $-p^2$ factor in the scoring rule; bidders only saw the relative score in percentages)
- *VarA* = contamination dimension of the winning bid
- *OptA* = contamination dimension of the bid with the maximum possible score
- *VarB* = delivery time dimension of the winning bid
- *OptB* = delivery time dimension of the bid with the maximum possible score
- *VarC* = price dimension of the winning bid
- *OptC* = price dimension of the bid with the maximum possible score (and a positive margin for the bidder)
- *TotEff, Eff, NPareto, Pareto, NParPlus, ParPlus* = dependent variables (see paragraph 5.5 for definitions)

ExpNo	Rounds	I.A.	UserID	Round	Profit	Score	VarA	OptA	VarB	OptB	VarC	OptC	TotEff	Eff	NPareto	Pareto	Npar-plus	Parplus
I	2	1	3	2	1	-921	4	2	2	5	82	71	1	0	22	0	16	0
II	2	1	3	2	3	-958	5	2	3	5	75	71	0.875	0	250	0	237	0
I	2	11	5	2	2	-902	2	2	2	5	85	71	0.75	0	0	1	0	1
II	2	11	2	2	3	-933	3	2	4	5	74	71	0.375	0	78	0	69	0
I	4	1	5	4	3	-904	2	2	2	5	86	71	0.75	0	0	1	0	1
II	4	1	2	4	4	-912	3	2	3	5	80	71	0.625	0	2	0	0	1
I	4	11	5	4	3	-904	2	2	2	5	86	71	0.75	0	0	1	0	1
II	4	11	2	4	2	-909	3	2	2	5	85	71	0.875	0	3	0	1	0
I	2	1	5	2	3	-903	2	4	1	3	90	75	0.75	0	49	0	37	0
II	2	1	2	2	3	-891	5	4	3	3	74	75	0.125	0	3	0	1	0
I	2	11	5	2	2	-889	4	4	3	3	77	75	0	1	0	1	0	1
II	2	11	5	2	3	-891	4	4	3	3	78	75	0	1	0	1	0	1
I	4	1	2	4	2	-886	4	4	3	3	76	75	0	1	0	1	0	1
II	4	1	2	4	2	-887	3	4	3	3	78	75	0.125	0	1	0	0	1
I	4	11	2	4	2	-886	4	4	3	3	76	75	0	1	0	1	0	1
II	4	11	2	4	2	-886	4	4	3	3	76	75	0	1	0	1	0	1
I	2	1	3	2	5	-897	6	8	1	1	84	75	0.25	0	11	0	7	0
II	2	1	3	2	4	-897	9	8	2	1	71	75	0.375	0	18	0	12	0
I	2	11	5	2	2	-885	8	8	1	1	77	75	0	1	0	1	0	1
II	2	11	5	2	3	-890	9	8	1	1	76	75	0.125	0	3	0	1	0
I	4	1	5	4	2	-895	5	8	1	1	83	75	0.375	0	17	0	12	0
II	4	1	3	3	3	-885	8	8	1	1	77	75	0	1	0	1	0	1
I	4	11	3	4	1	-888	6	8	1	1	80	75	0.25	0	9	0	6	0
II	4	11	3	3	3	-893	6	8	1	1	82	75	0.25	0	11	0	7	0
I	2	1	3	2	1	-848	7	10	3	4	67	53	0.625	0	24	0	17	0
II	2	1	2	2	2	-850	7	10	3	4	68	53	0.625	0	27	0	20	0
I	2	11	3	2	2	-842	9	10	3	4	64	53	0.375	0	4	0	1	0
II	2	11	3	2	3	-859	8	10	2	4	72	53	0.75	0	51	0	37	0
I	4	1	3	4	2	-846	7	10	4	4	63	53	0.375	0	11	0	5	0
II	4	1	4	4	3	-845	9	10	3	4	65	53	0.375	0	11	0	7	0
I	4	11	2	4	2	-837	10	10	4	4	56	53	0	1	0	1	0	1
II	4	11	5	4	1	-855	9	10	2	4	70	53	0.625	0	21	0	13	0
I	2	1	3	2	4	-869	7	8	2	4	75	60	0.625	0	32	0	22	0
II	2	1	4	2	2	-862	7	8	3	4	71	60	0.375	0	15	0	10	0
I	2	11	2	2	3	-864	5	8	4	4	69	60	0.375	0	23	0	15	0
II	2	11	3	2	6	-864	8	8	3	4	70	60	0.25	0	4	0	2	0
I	4	1	4	4	4	-864	8	8	3	4	70	60	0.25	0	8	0	5	0
II	4	1	5	4	4	-870	6	8	3	4	75	60	0.5	0	9	0	4	0
I	4	11	3	3	2	-851	7	8	4	4	63	60	0.125	0	0	1	0	1
II	4	11	4	3	2	-859	8	8	3	4	68	60	0.25	0	7	0	4	0
I	2	1	3	2	3	-1014	6	2	3	2	72	84	0.75	0	1079	0	1057	0
II	2	1	5	2	4	-935	2	2	4	2	79	84	0.5	0	108	0	99	0
I	2	11	5	2	2	-902	2	2	2	2	85	84	0	1	0	1	0	1
II	2	11	2	2	3	-910	3	2	3	2	79	84	0.375	0	2	0	0	1
I	4	1	2	4	2	-908	2	2	3	2	81	84	0.25	0	0	1	0	1
II	4	1	2	3	5	-935	2	2	4	2	79	84	0.5	0	73	0	65	0
I	4	11	5	4	3	-904	2	2	2	2	86	84	0	1	0	1	0	1
II	4	11	5	2	1	-906	2	2	3	2	80	84	0.25	0	9	0	5	0

APPENDIX III: AN OVERVIEW OF THEORIES OF THE MARKET

The purpose of this appendix is to give an overview of the various theories of the market that exist in the literature, in order to identify relevant factors that should be included in a theory of electronic markets.

Theories of the market can be distinguished along two separate dimensions: whether a market is viewed as a state or as a process and whether markets are primarily viewed as allocation mechanisms or as social structures. The state/allocation mechanism view has traditionally been the province of neoclassical economics, industrial organization and the economics of information, the state/social structure view that of (economic) sociology and new institutional economics and parts of the marketing literature. Process/allocation mechanism views are particularly associated with Austrian economics, but the emergent literature on market microstructure tends to take a process perspective as well. The process/social structure view does not have a specific body of theory associated with it, but the articles that espouse such a view can be found mainly in the marketing and management literature (see Table A.III.1). Please note that this classification only intends to show where the main body of knowledge regarding a particular market view resides and it should not be interpreted the other way round. It is intended as the first step towards making sense of the wide variety of literature on markets by showing the main underlying dimensions on which the views differ. The next sections each describe one of the cells in this table, after which the final section summarizes.

Table A.III.0.1 Classification of theories of markets and their main literature counterparts

Nature of theory	Allocation mechanism	Social structure
Dynamic	Austrian Economics Market Microstructure	Various/scattered (Management, Marketing)
Static	Neoclassical Economics Industrial Organization Economics of Information	Economic Sociology New Institutional Economics Marketing

View of market

Markets as a static allocation mechanism

The canonical market model is that of neoclassical economics, which is rooted in the definitions originally set forth by Cournot and Marshall:

> "Economists understand by the term *Market*, not any particular market place in which things are bought and sold, but the whole region in which buyers and sellers are in such free intercourse with one another that the prices of the same goods tend to equality easily and quickly." (Cournot, 1927 [1838])

> "The more nearly perfect a market is, the stronger is the tendency for the same price to be paid for the same thing at the same time in all the parts of the market." (Marshall, 1961 [1920])

Two cornerstones of these definitions (although not explicit in the quotes cited above) are the assumptions of perfect information and perfect competition. Perfect information means that all actors in the market automatically and costlessly have all the relevant information necessary to determine their market processes. Perfect competition means that buyers and sellers are so small, relative to the size of the market, that none of them can affect the market price. Without these, the 'law of one price' as described in Cournot and Marshall's definitions cannot hold. This model is of course an ideal type and is not particularly likely to occur in the real world and even in markets that closely approximate this ideal type, price behavior is found that is inconsistent with the neoclassical predictions (Baker, 1984; Graddy, 1995).

Therefore, economists started to relax the assumptions of perfect competition and perfect information, resulting in the fields of Industrial Organization (IO, mainly focusing on imperfect competition) and economics of information (mainly focusing on imperfect information). While much progress has been made in both fields in analyzing specific situations, there is a lack of general results, as illustrated by the following two quotes:

> "…the status of the theory of oligopoly is that of exemplifying theory. We know that a lot of things *can* happen. We do not have a full, coherent theory of what *must* happen or a theory that tells us how what happens depends on well-defined, measurable variables. […] We need a generalizing theory as to how that context influences the outcome." (Fisher, 1989, p. 118, emphasis in original)

> "Since results often seem to depend, so sensitively, on the particular information assumptions employed, how are we to know what is the correct model?" (Stiglitz, 2000, p.1470)

Therefore, a full survey of all the results obtained in the IO and economics of information literature is beyond the scope of this chapter, especially since several textbooks in IO, economics of information and game theory exist, in particular Tirole (1988) and Fudenberg and Tirole (1991).

A third implicit assumption of the perfect market is that traders act as maximizing their (expected) utility. Von Neumann and Morgenstern (1947) later formalized this notion. This assumption of 'rationality' of economic man has been intensely debated, particularly from a psychological point of view, and the three most prominent criticisms are described below.

Simon (1955) argued that in reality, humans have limited information-processing capacity and thus are subject to bounded rationality, which leads to satisficing behavior instead of maximizing behavior. Kahneman and Tversky (1979) demonstrated a wide variety of cognitive phenomena that underlie human choice behavior (such as the Allais paradox (Allais, 1953)) that are inconsistent with expected utility maximizing behavior. They formulated their famous prospect theory as an alternative, descriptive theory of human choice under risk. Another criticism centered on the ambiguity (or uncertainty[11]) involved in many economic decisions (Ellsberg, 1961). Einhorn and Hogarth (1985) proposed a model of ambiguity aversion to deal with such situations.

All three models above have found widespread empirical support as an improved model of individual choice behavior (Camerer and Weber, 1992). While many economists acknowledge the superior descriptive validity of those models, they maintain that at the market level, i.e. the aggregation of a set of individual choices, expected utility does predict well (Plott, 1986).

A few experimental tests of this aggregate rationality hypothesis have been conducted, that have produced mixed, but generally supportive evidence. Camerer (1987) studied individual probability judgments and found that their accuracy in market settings (compared to individual settings) improved, particularly as subjects became more experienced, although it did not disappear completely. Gode and Sunder (1993) conducted a fascinating computer simulation study to investigate aggregate rationality in double auctions (the canonical market prototype used in laboratory experiments). In principle, their software agents submitted random bids or asks. They then imposed a budget constraint, i.e. agents were not allowed to sell below their cost or buy above their value, but no further restrictions regarding profit maximization or learning (such are expected to lay a role in human trading behavior) were imposed. The results of the markets with these 'zero-intelligence traders' were virtually indistinguishable from the results with human traders and they conclude that markets "…may generate aggregate rationality not only from individual rationality, but also from *individual*

[11] One way of relating risk, uncertainty and ambiguity is the following: when the probabilities of each outcome are known, there is risk, but when they are unknown, there is uncertainty or ambiguity (the two are often used interchangeably). From a subjective expected utility perspective, a distinction between known and unknown probabilities is meaningless, because subjective probabilities are always known to the decision-maker, but empirical evidence suggests that the distinction is meaningful (Camerer, 1995).

irrationality." (Gode and Sunder, 1993, p. 136, emphasis added). Put differently, their results suggest that the allocation mechanism itself (in their case, the double auction), when coupled with a simple budget constraint, can be an important determinant of performance, relatively independent of the participants in that mechanism. Evans (1997) studied violations of the betweenness axiom of expected utility in markets and found that fewer and also less severe violations occurred in a market setting. However, she argued that this may be not so much due to induced rationality by competition, but rather to the statistical role of markets as aggregating price to a single statistic such as the winning bid, which lends further support to Gode and Sunder's conclusion. In this regard, compare also recent work by Fehr and Schmidt (1999), who show that in a setting where both competitive and cooperative players exist, the microeconomic mechanism can determine which type of behavior will prevail in equilibrium.
Myagkov and Plott (1997) tested a slightly modified version of prospect theory in a market setting and they found considerable support for the occurrence of risk-seeking behavior when faced with losses, which is a central element of prospect theory. However, they also found that prices did eventually converge to the equilibrium predicted by expected utility models, thus lending additional support to the aggregate rationality hypothesis. Finally, Sarin and Weber (1994) tested the Einhorn-Hogarth (1986) ambiguity model in a market setting and found support for the hypothesis of ambiguity aversion in markets, i.e. subjects paid less for ambiguous assets.

The discussion on aggregate rationality is also echoed in the debate on the Efficient Market Hypothesis (EMH), (Fama, 1970). The EMH states that at any given point in time, markets incorporate all relevant information in prices, thus resulting in an (informationally) efficient market that yields equilibrium prices. If 'all relevant information' is interpreted as reflecting all private information, a market is strong-form efficient, if it is interpreted as reflecting all publicly available information, a market is semi-strong-form efficient (the common interpretation of the EMH). In response to criticism from behavioral finance researchers, who for instance argue that the stock market overreacts (DeBondt and Thaler, 1985) and therefore can not be efficient, Fama argued that such overreactions are chance results and that on aggregate, markets are efficient (Fama, 1998).

Markets as a dynamic allocation process

The view of markets as a state depends crucially on the fact that markets are presumed to be in equilibrium. Austrian economics, particularly through the writings of Hayek (1945, 1978), Mises (1949) and Kirzner (1973, 1997), takes issue with this static description of markets and emphasizes the dynamic, process nature of a market. In the Austrian view, or market-process-theory as it has become known recently, markets are never in equilibrium, even though they may be moving *towards* an equilibrium (some Austrian economists are even more radical and dispute this teleological point, see for instance Buchanan and Vanberg (1992) and Lachmann (1986)). In the Austrian view, a theory of markets should not focus on the properties of equilibria, but instead on market behavior in disequilibrium, in other words: on the market process.

Crucial to the market-process-theory is what Hayek termed 'the knowledge problem':

> "The economic problem of society […] is a problem of the utilization of knowledge which is not given to anyone in its totality." (Hayek, 1945, p. 520)

Hayek then argued that the price system is perfectly suited to communicating this widely dispersed knowledge, as prices convey all the relevant knowledge to the decision makers. This statement has subsequently become known as the 'Hayek Hypothesis' and has received considerable experimental support (Smith, 1982). Although both stress the sufficiency of prices in communicating information, the distinction with the Efficient Market Hypothesis is worth noting. In the EMH, the market is perceived to be in equilibrium and as all relevant information is incorporated in that equilibrium, there is no telling what the price will do next and it will tend to follow a random walk. In the Hayekian view however, price still communicates all the relevant information, but it communicates it to the *decision-maker*, who then must decide how to act upon this information. Because of a *change* in the economic system, prices change and local decision-makers must adapt their behavior. This emphasizes the process nature of the market.

A second crucial aspect market-process theory, particularly through the works of Kirzner (1973, 1997) is that of the interrelated concepts 'ignorance' and 'entrepreneurial discovery', which will be described below. As a market is in

disequilibrium, this means that some of the knowledge necessary for utility maximization (which would restore market equilibrium) is unavailable. This unavailability is of a different kind than that in the search models of information economics (such as Stigler (1961)), where decision-makers can specify the set of possible outcomes in advance and attach consistent probabilities to them. Rather, this unavailability refers to the fact that the decision-maker is unaware that knowledge relevant to his decision even *exists*, which is what is meant by ignorance (Kirzner, 1973; Ikeda, 1990). In market-process theory, it is the entrepreneur who discovers such previously unknown information and it is this entrepreneurial discovery that is the driving force behind price adjustments in the market. Entrepreneurship in this sense can be thought of as alertness to perceived profit opportunities. And even though an entrepreneur does not know what new information to expect (or even if he should expect new information at all!), he is aware of the possibility of being surprised by new information and thus is alert for such discoveries. Note that the concept of ignorance implies that, since not all the relevant information is available, discovered information may point *away* from the equilibrium, thus leading to entrepreneurial mistakes.
Market-process theory has long resisted formalization, partly due to a very critical stance of market-process theorists towards mathematical modelling in general (see Foss (2000) for a signal that this may change) and partly because the mathematical tools for dealing with ignorance and discovery were lacking. However, recently Yates (2000) has constructed a formal model of the market process, outlined the conditions under which the market process converges to equilibrium and showed that this equilibrium has quite different welfare properties compared to the static Walrasian equilibrium.

In the last two decades, a different stream of literature (coming mainly from finance researchers) has also emphasized this process aspect under the heading of market microstructure. Not satisfied with the elegant but simple model of neoclassical economics, particularly when confronted with the wide variety of financial markets and trading mechanisms that exist, they developed an alternative process view of markets based around the tenet that:

> "If trading involves more than simply matching supplies and demand in equilibrium, then the trading mechanism may have an importance of its own." (O'Hara, 1995, p. 4-5)

Of particular interest in market microstructure are two different roles of information in determining the market process. The first role is information that traders may or may not have a priori, i.e. heterogeneously informed traders (Glosten and Milgrom, 1985). Important questions in this regard are how much profit informed traders can make from their superior information and how quickly (if at all) their information is indirectly revealed to the uninformed traders through the trades of the informed traders. A second important role of information is the information that is directly revealed by the trading mechanism, i.e. the issue of market transparency. Central questions are how revealing trading information such as order flow information (Madhavan, 1992), quotes (Biais, 1993) and trader identity (Forster and George, 1992) influences trading behavior and market performance.

In general, market microstructure research has succeeded in highlighting the conundrum "the devil is in the details". Seemingly innocuous assumptions in the analytical models about the details of trading mechanisms and what information traders (can) have, turn out to matter a great deal in determining market process. However, the other side of this coin is that (much like the case in the IO and economics of information literature cited above) as a consequence general results do not seem to exist:

> "…the complexity of many performance issues defies easy characterization, and the simplifications needed to ensure tractable analyses limit the generality of the resulting policy recommendations." (O'Hara, 1995, p. 252)

Recent work in experimental finance (Flood, Huisman, Koedijk and Mahieu, 2000; Bloomfield and O'Hara, 2000) looks to shed some light on which analytical models correspond to actual market processes.

Markets as a static social structure

One critique on the economic theories of markets came from New Institutional Economics (NIE), particularly through the works of Coase, Williamson and North, who looked at the market as a special kind of (social) institution. Institutions are defined as "…the humanly devised constraints that structure political, economic and social interaction." (North, 1991). At the basis of New Institutional Economics are the observations that humans are boundedly rational and that at least some humans are inclined towards opportunism (Williamson, 1975, 1985). The former gives rise to search costs, i.e. locating potential buyers and sellers (see Stigler, 1961) and measurement costs, i.e. verifying that the product to be acquired has the desired qualities (see Barzel, 1982). The latter gives rise to enforcement costs, i.e. ensuring that the contract is executed honestly (Williamson, 1985). Without proper institutional arrangements to at least partially alleviate such costs, market processes cannot function, which results in a view of the market as an institution in its own right (Coase, 1988). Some of the institutional arrangements necessary are the establishment of property rights, law and law enforcement, reputation mechanisms and product description standards. The main goal of these institutions is to reduce the amount and imperfection of information necessary for a transaction to take place (thus ameliorating problems of bounded rationality) and to provide incentives for honest behavior and/or deterrents for dishonest behavior (thus ameliorating problems of opportunism). Although institutional change is a central theme in NIE (North, 1991), in the actual literature most institutions are presumed to be fairly stable and tend to be analyzed in terms of the economic problem it solved, giving rise to a rather static view of institutions.

Another important criticism of viewing markets solely as allocation mechanisms is that the atomized conception of hyperrational market actors in that view is unrealistic. Not just incorrect from a psychological perspective (see the discussion above about individual and aggregate rationality), but particularly incomplete from a sociological perspective. Markets are populated by humans, who have not only preferences, but also values and norms and most importantly, social relations to other market actors (Baker, 1984; Granovetter, 1985; and for auctions in particular, Smith (1989)). To put it succinctly, markets do not exist in a vacuum. As Granovetter has pointed out, even though social concepts such as customs, habits and norms certainly influence economic processes, it is not enough to postulate them as simple determinants of economic action. For doing so would also decouple individuals from their social context and hence introduce an oversocialized form of atomization:

> "In the undersocialized account, atomization results from narrow pursuit of self-interest; in the oversocialized one, from the fact that behavioral patterns have been internalized […]. That the internalized rules of

> behavior are social in origin does not differentiate this argument decisively from a utilitarian one […]. Under- and oversocialized resolutions of the problem of order thus merge in their atomization of actors from their immediate social context." (Granovetter 1985, p.485)

The main contribution from (economic) sociologists is that market processes is closely embedded in networks of interpersonal or interfirm relations, i.e. a market is a social structure. Around the same time, both White (1981) and Baker (1984) showed empirically that introducing a social structural perspective (in the form of networks) can explain certain aspects of market processes (particularly the occurrence of certain trading patterns) that traditional economic analysis cannot. White focused on the provocative, yet rarely addressed question "Where do markets come from?" (the title of his 1981 paper) and the related questions of why certain markets persist or fail. His key insight was that:

> "Markets are not defined by a set of buyers […] nor are the producers obsessed with speculations on an amorphous demand. I insist that what a firm does in a market is to watch the competition in terms of observables." (White, 1981, p. 518)

The observables that are signaled or communicated consist of the revenue that a certain firm received for volume shipped. The set of these observables (one for each firm in the market) collectively define a 'market schedule', which can be viewed as a generalization of price. Based on this market schedule, heterogeneous firms try to find market niches ('roles') for their differentiated products such that these roles are sustainable, i.e. the market schedule is reproduced by their actions. Based on the parameters of producer cost schedules and buyer valuation schedules (both dependent on volume and quality), White showed that it is only a restricted set of parameters that can lead to sustainable market schedules and illustrated it using data from a number of US industries. Supply equalling demand is an outcome of his model, not the defining characteristic it is in most economic models. Thus casting markets in terms of relations among producers, he opened the door for a social structural analysis of markets.

The second important contribution came from Baker (1984), who investigated floor trading on a major securities exchange. Although securities market most closely approximate the ideal type of atomized, rational actors in economic theory,

Baker showed that that market could be characterized as a social structure, because (at least) two very different types of networks among traders could be distinguished, a sparse and a dense one. Moreover, he showed that these distinct social structural patterns "…dramatically influenced the direction and magnitude of price volatility." (Baker, 1984, p. 803), with the dense network having a much lower price volatility than the sparse network.
Burt (1992) later extended the social structural view to an analysis of competition in a wide variety of contexts, when he showed that actors occupying a network position that is rich in structural holes, i.e. fulfilling a bridging function between distinct parts of the network, have significant competitive advantages. All these models share the precept that social structure is a determinant of market processes that had been neglected in economic theory, not just for businesses, but also for individual consumers (DiMaggio and Louch, 1998).

Although not phrased as a critique of the economic models of markets or drawing on the sociological models described above, recent research in marketing (although it can be traced back to the early work of Bagozzi (1974, 1975)) has been developing along the same lines. Emphasizing in particular the relationship aspect of the exchanges that occur among traders in markets, research has focused on non-economic determinants of particular types of exchange relationships. For instance, in high-speed environments, buyers are more likely to stick to existing suppliers (Heide and Weiss, 1995). Podolny (1993, 1994) showed that status was an important determinant of which tiers existed among investment banks. In consumer markets, social capital of the seller and information flows among consumers were found to significantly influence purchases (Frenzen and Davis, 1990; Frenzen and Nakamoto, 1993).

Markets as a dynamic social structure

The studies cited in the last paragraph, although primarily taking the social structure of the market as a given, could also be seen as the first step towards a process theory of markets as social structures. They focus on the first step in such a process, namely the initiation of an exchange relationship. A full theory would also take into account how such relationships subsequently are maintained as part of the market process. Such a theory is not yet present, but there are some studies that point in that direction. Porac and coauthors highlighted the way in which market boundaries and market actions are created by the joint actions from producers and consumers, i.e. the social construction of the market (Porac et al., 1995; Rosa et al., 1999). Abolafia and Kilduff (1988) showed that the crisis in the 1980 silver market was not a simple economic phenomenon, but a complex set of interactions among the traders that both created and resolved the market bubble. Smith emphasizes similar points as Porac, Abolafia and Kilduff in an extensive investigation of auctions (Smith, 1989). Uzzi (1996, 1997) discussed how market relationships and social relationships in the New York knitwear industry overlapped and how they mutually created and sustained one another. A central theme in his work was that the open climate, created particularly through information exchange, resulted in a trusting climate between the various organizations. This is despite the (in principle) adversarial nature of the competition, which would seem rife with possibilities for opportunistic behavior and exploitation of bargaining power. Cannon and Perreault (1999) also highlighted the importance of information exchange for maintaining successful buyer-seller relationships.

Summary

A theory of the market has come a long way from the original neoclassical models of markets as static allocation mechanisms. Critics of the descriptively unrealistic nature of that model have focused on two aspects: the nature of the market as a process instead of an equilibrium state and the necessity of viewing market processes in the social and institutional context in which they are situated. Although both views by themselves contribute to a more realistic model of market processes, a comprehensive model would need to take both aspects into account. Despite this, the model developed in this chapter only touches briefly upon the social structure issues, and the main focus is on market process issues.

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SAMENVATTING (IN DUTCH)

De opkomst van het Internet de afgelopen jaren is zo snel gegaan, dat het moeilijk is om voor te stellen dat nog maar tien jaar geleden het World Wide Web volledig in de kinderschoenen stond en ook email alleen voorbehouden was aan een zeer select groepje mensen. Ook voor bedrijven heeft het Internet grote gevolgen gehad: hoewel nog lang niet zo grootschalig als sommigen hadden voorspeld, vormt het kopen en verkopen van goederen en diensten via het Internet inmiddels een vast onderdeel van veel bedrijven. Met name de opkomst van elektronische markten en veilingen in het bijzonder is in dit opzicht opmerkelijk. Het bedrijf eBay, dat zich met name richt op verzamelaars en de markt voor tweedehands goederen, verzorgt nu 4 miljoen veilingen per dag en is een van de weinige Internetbedrijven die structureel winst maken. Ook wanneer het gaat om in- en verkoop tussen bedrijven, spelen elektronische markten een steeds belangrijkere rol. Nieuwe Internetbedrijven als Covisint in de automobielindustrie, Transora in de voedselindustrie, ChemConnect in de chemische sector of FreeMarkets voor industriële goederen halen vele miljoenen omzet per jaar, alsmede vele andere organisaties die zelf veilingen opzetten voor eigen gebruik met behulp van de vele veilingtechnologie-leveranciers.
Dergelijke ontwikkelingen roepen dan ook de vraag op hoe succesvol dergelijke markten nou daadwerkelijk zijn en hoe je de prestatie van een elektronische markt kunt verbeteren. Een manier om zulke vragen te beantwoorden is door succesvolle en niet-succesvolle elektronische markten te vergelijken en hieruit kritische succes- en faalfactoren af te leiden. Een andere manier is om factoren te zoeken die de prestatie van een elektronische markt kunnen beïnvloeden en vervolgens te onderzoeken wat het effect is van die factoren. Deze laatste aanpak wordt gevolgd in deze dissertatie.

Een belangrijk uitgangspunt in deze dissertatie is dat wat de kern van wat er in markten gebeurt, niet zozeer het uitwisselen van vraag en aanbod zelf is, maar het uitwisselen van *informatie* over vraag en aanbod. Handelaren wisselen informatie uit met elkaar over waar ze naar op zoek zijn of wat ze te verkopen hebben en wat ze hiervoor willen betalen of ontvangen. Dit soort informatie-uitwisselingsprocessen (oftewel marktprocessen) bepalen wat de uitkomst van de markt is (de transacties die tot stand komen) en daarmee de prestatie van de markt.

Deze focus op het uitwisselen van informatie betekent dat het belangrijk is om te kijken naar “welk type informatie bij wie beschikbaar is, of wanneer het op welke manier aan wie beschikbaar gemaakt wordt gedurende het marktproces”. Dit laatste is wat in deze dissertatie geïntroduceerd wordt als zijnde de *informatie-architectuur van de markt*. Hierbij worden drie categorieën informatie onderscheiden: informatie over het product zelf, informatie over de toestand van de markt en informatie over het marktproces zelf, d.w.z. gekoppeld aan een specifieke transactie. Tezamen vormen deze drie categorieën de marktinformatie-verzameling.
Het begrip van informatie-architectuur wordt extra relevant in de context van elektronische markten, omdat informatie- en communicatietechnologie (ICT) grote invloed kan hebben op welke informatie beschikbaar is en hoe deze gepresenteerd wordt. In een elektronische markt kan bijvoorbeeld het vergelijken van verkopers bijvoorbeeld veel makkelijker zijn (‘de concurrentie is een muisklik verwijderd’), maar omdat het produkt niet meer fysiek aanwezig is in een elektronische markt, moeten er ook keuzes gemaakt worden of produkten weergegeven worden door middel tekst, foto’s, video, geluid of een combinatie hiervan. Dit alles leidt dan ook tot de centrale onderzoeksvraag van dit proefschrift, namelijk: “Hoe beïnvloedt ICT de informatie-architectuur van de markt en hoe beïnvloedt dit de marktprocessen, de marktuitkomst en de marktprestaties?”.
Deze vraag wordt als volgt beantwoord. Als eerste worden er in hoofdstukken 3, 4 en 5 drie aparte empirische studies uitgevoerd waarin telkens de invloed van een specifieke vorm van ICT op een van de drie informatie-categorieën van de informatie-architectuur in een specifieke markt wordt geanalyseerd. Als tweede wordt in hoofdstuk 6 een synthese van deze studies gepresenteerd in de vorm van een algemeen theoretisch model van elektronische markten.

De eerste studie behandelt de invloed van informatie over de kwaliteit van het product. Zoals hierboven al opgemerkt, zijn er in een elektronische markt verschillende manieren om informatie over een product te presenteren. Hierdoor hebben kopers meer of minder (of simpelweg andere) informatie tot hun beschikking om de kwaliteit van het produkt te beoordelen en dit kan invloed hebben op de prijs die ze willen betalen. Dit is onderzocht bij een grote bloemenveiling. Normaal gesproken worden de bloemen op een kar de veilingzaal in gereden, waar ze getoond worden aan de bieders en er vervolgens op geboden wordt door middel van de bekende veilingklok. Dit systeem met veilingkarren brengt de nodige logistieke complexiteit met zich mee en om deze te reduceren werd voor de bloem Anthurium een nieuwe veilvorm ingevoerd, het zogenaamde beeldveilen. Hierbij bleven de bloemen in het magazijn, maar kregen de bieders in de veilingzaal een standaardfoto van de bloem te zien, samen met de overige produktgegevens (zoals wie de kweker was en wat diameter en steellengte van de bloem waren). In de nieuwe situatie misten bieders echter wel bepaalde informatie over de kwaliteit van de bloem, met name de stijfheid van de bloemsteel, wat een belangrijke indicator is van de versheid van de bloem. Door het ontbreken van zulke productkwaliteitsinformatie zullen bieders de kwaliteit behoudend inschatten en dus gemiddeld lagere prijzen betalen. Statistisch onderzoek van de bloemenprijzen van Anthuriums voor en na de invoering van beeldveilen bevestigde dit: de prijzen bij beeldveilen lagen ongeveer 2% lager dan daarvoor. Informatie over produktkwaliteit is dus een belangrijke categorie van informatie die kan veranderen onder invloed van ICT, wat weer gevolgen heeft voor de prijzen in een elektronische markt.

De tweede studie keek onder andere naar een tweede categorie informatie die van belang werd geacht: informatie over de toestand van de markt, zoals bijvoorbeeld het aantal aanwezige handelaren. Dergelijke informatie staat weliswaar los van een specifieke transactie, maar is wel een indicator over de algehele toestand van de markt en kan daardoor dus van belang zijn voor handelaren. Dit werd onderzocht bij dezelfde bloemenveiling als de studie naar beeldveilen. De veiling bood bieders de mogelijkheid van het Kopen Op Afstand (KOA). Hierbij hoefden bieders niet meer in de veilingzaal aanwezig te zijn, maar in plaats daarvan boden ze via de computer die verbonden was met de centrale computer van de bloemenveiling. Dergelijke KOA-kopers zagen de bloem dus niet meer fysiek, ook geen plaatje, in tegenstelling tot de bieders in de veilingzaal, die de bloem nog wel gewoon zagen. Doordat beide groepen tegelijkertijd op dezelfde bloemen boden, is een gedetailleerde vergelijking van biedgedrag mogelijk tussen online (KOA) en offline (veilingzaal) kopers. Een belangrijk verschil tussen de KOA-kopers en de veilingzaal-kopers was dat de KOA-kopers door middel van het computersysteem lagere zoekkosten hadden: ze hadden een volledig overzicht over alle 13 veilklokken en konden met een toetsdruk wisselen van klok, in plaats van daarvoor fysiek naar een andere plek te moeten lopen. Bovendien waren KOA-kopers ook nogal eens aangesloten op de KOA-systemen van concurrerende veilingen,

waardoor voor hen de transparantie van de markt nog groter werd. Dit alles zou moeten leiden tot lagere prijzen voor de KOA-kopers.
Binnen de KOA-kopers zelf was er onderscheid te maken tussen twee groepen: de interne en externe KOA-kopers. De interne KOA-kopers hadden hun kantoor op het complex van de veiling zelf, terwijl de externe KOA-kopers vanuit hun kantoor in andere plaatsen boden. Het feit dat de interne KOA-kopers hun kantoor op het veilingcomplex hadden, bracht twee voordelen met zich mee ten opzichte van de externe KOA-kopers. Ten eerste hadden ze de mogelijkheid om 's ochtends de bloemen in het magazijn te inspecteren, waardoor ze productkwaliteit beter konden inschatten dan de externe KOA-kopers, die niet de mogelijkheid van de magazijninspectie hadden. Daarnaast konden interne KOA-kopers de beelden zien van de beveiligingscamera's die in elke veilingzaal hingen. Hierdoor konden ze bijvoorbeeld zien wat de oorzaak was van eventuele vertragingen in het veilproces, maar ook konden ze zien hoeveel bieders er in de veilingzaal aanwezig waren. Externe KOA-kopers misten deze informatie over de toestand van de markt.
Een statistische vergelijking van het biedgedrag tussen interne KOA-kopers, externe KOA-kopers en veilingzaal-kopers bracht interessante verschillen aan het licht. KOA-kopers als geheel boden inderdaad gemiddeld lager dan de veilingzaal-kopers, zoals verwacht op grond van de lagere zoekkosten en grotere markttransparantie. Wanneer de KOA-kopers gesplitst werden in de interne en externe KOA-kopers, bleek dat dit verschil echter volledig toe te schrijven viel aan het biedgedrag van de interne KOA-kopers. De externe KOA-kopers betaalden gemiddeld dezelfde prijzen als de kopers in de veilingzaal, terwijl de interne KOA-kopers structureel lagere prijzen voor de bloemen betaalden dan de externe KOA-kopers en de bieders in de veilingzaal. Het effect van de lagere zoekkosten voor externe KOA-bieders ten opzicht van veilingzaal-kopers werd dus genivelleerd door het ontbreken van informatie over de productkwaliteit (middels de magazijninspectie) en informatie over de toestand van de markt. Interne KOA-kopers lijken in dit opzicht het beste van twee werelden te hebben, omdat ze zowel de lagere zoekkosten van het KOA-systeem hebben, alsook voldoende informatie over productkwaliteit en de toestand van de markt.

Deze twee studies gingen met name over het effect van een ICT-verandering op een bestaande markt. ICT kan echter ook nieuwe marktmechanismen mogelijk maken die daarvoor praktisch gezien moeilijk uitvoerbaar waren. Een voorbeeld

hiervan is de elektronische multidimensionale veiling. Traditioneel gaat het in een veiling, naast het vinden van een koper, om het vaststellen van de prijs. Wanneer het gaat om een vast produkt dat verkocht moet worden, is dit voor de hand liggend. Echter, wanneer we niet kijken naar een dergelijke verkoopveiling, maar een inkoopveiling, wordt de zaak anders. In een inkoopveiling zijn de bieders de verkopers/leveranciers en de veilingmeester is de koper. We spreken dan ook wel van een vraaggestuurde veiling, omdat de vraag van de koper het uitgangspunt is van de veiling. In veel gevallen zijn dan behalve prijs ook factoren als kwaliteit, levertijd, garantie-bepalingen en dergelijke van groot belang. In plaats van deze extra dimensies van te voren vast te stellen en vervolgens een veiling op prijs te houden, worden deze dimensies een integraal onderdeel van het veilproces. Bieders doen dus nu een bod op meerdere dimensies, dat door de veilingmeester beoordeeld wordt totdat uiteindelijk de beste (en dus niet per se de goedkoopste!) bieder wint. In een dergelijke markt kan beter ingespeeld worden op de voorkeuren van de koper en de relatieve sterktes van de verkopers, zodat er win-win situaties kunnen ontstaan. Bovendien vindt voor de verkopers concurrentie nu plaats op een zuiverder manier dan alleen maar op prijs.
Bij het opzetten van dit soort nieuwe veilmechanismen moeten ten eerste de regels van het veilmechanisme ontworpen moeten worden, zoals wanneer de veiling eindigt en wie dan de veiling wint tegen welk bod. Tegelijkertijd moet echter ook de informatie-architectuur van de markt ontworpen worden. Dit vormt een -vaak onderschatte- complicatie, omdat de keuzes die gemaakt worden ten aanzien van welke informatie de bieders krijgen tijdens het veilproces over alle biedingen die gedaan zijn (m.a.w. de derde informatiecategorie van de informatie-architectuur: marktproces-informatie), de resultaten van het veilingmechanisme wel eens flink zouden kunnen beïnvloeden.
De derde studie heeft dit laatste nader onderzocht. Er is een prototype gebouwd van een elektronische multidimensionale veiling en hiermee zijn laboratoriumexperimenten uitgevoerd. In deze experimenten bieden studenten in een multidimensionale veiling over meerdere ronden en onder verschillende informatie-architecturen. In het ene geval kregen ze aan het eind van de ronde alleen het hoogste bod te zien, waarna een nieuw bod kon worde geplaatst in de volgende ronde. In het andere geval kregen ze alle biedingen te zien die in die ronde gedaan waren, alsmede de score van elk bod volgens de afwegingen van de veilingmeester. Deze laatste informatiearchitectuur bleek een duidelijke verbetering op te leveren van de efficientie en optimaliteit van de markt. Hierbij

moet wel aangetekend worden dat deze voordelen vooral optraden wanneer de veiling kort (2 ronden) duurde. Wanneer de veiling langer duurde (4 ronden), was de toegevoegde waarde van de extra informatie beduidend kleiner. Dit zou erop kunnen wijzen dat er een proces van informatie-verzadiging optreedt in de markt: voorbij een bepaald punt heeft het transparanter maken van de markt nog nauwelijks positieve gevolgen voor de prestatie van de markt.

Tot slot is in hoofdstuk 6 een algemeen antwoord gegeven op de onderzoeksvraag door een synthese van de drie voorgaande studies, tezamen met additionele literatuur. Dit heeft geleid tot een theorie van elektronische markten die de relatie tussen ICT en de prestatie van elektronische markten. Kort gezegd verloopt deze relatie langs vijf stappen:

1. Een verandering in ICT verandert de informatie-architectuur van de markt.
2. De informatie-architectuur bepaalt welke informatie beschikbaar is voor de handelaren in de markt (de marktinformatie-verzameling).
3. De marktinformatie-verzameling bepaalt (mede) hoe de informatie-uitwisselingsprocessen tussen handelaren verlopen.
4. De informatie-uitwisseling (het marktproces) leidt uiteindelijk tot een uitkomst van de markt, te weten een verzameling transacties.
5. Het marktproces en de uitkomst van de markt bepalen de prestatie van de markt, afhankelijk van de gehanteerde prestatie-criteria.

De hoofdbijdrage van dit proefschrift is gelegen in het empirisch aantonen dat de informatie-architectuur van de markt een belangrijke factor is die de prestatie van elektronische markten verklaart. Dit betekent voor ontwerpers van markten, handelaren en onderzoekers, dat veel aandacht gegeven moet worden aan de processen van informatie-uitwisseling bij het ontwerpen en onderzoeken van markten. Een andere belangrijke bijdrage is de ontwikkeling van een model van elektronische markten dat breder is dat het transactiekosten-perspectief dat tot dusverre vooral gehanteerd werd. Tot slot is de ontwikkeling van de elektronische multidimensionale veiling zowel vanuit theoretisch als praktisch oogpunt zeer interessant. Dit is bij uitstek een onderwerp waarin wetenschappelijk onderzoek en praktijk elkaar prima kunnen versterken, opdat elektronische markten ook daadwerkelijk waarde creëren voor alle partijen.

CURRICULUM VITAE

Otto Koppius studied Applied Mathematics at the University of Twente in the Netherlands, with a major in graph theory. During his studies, he spent several months at the University of South Australia, working on a project involving the optimal layout of mineshafts. In June 1997, he received his M.Sc. degree for a thesis on the novel graph-theoretic problem of finding degree-preserving spanning trees, which arose from an application in water distribution networks. In September 1997, he took up a position as Ph.D. student at the department of Decision and Information Sciences at the Rotterdam School of Management, Erasmus University. In 1998, he was one of the recipients of a grant from the Carnegie Bosch Institute at Carnegie-Mellon University, for a project on electronic sourcing strategy. The same year, his dissertation proposal on electronic multidimensional auctions was runner-up in the contest for “Best E-Commerce Thesis Proposal”, organized by IBM Research’s Institute for Advanced Commerce. The following year, he spent three months as a visiting researcher at the University of Michigan, as well as three months at the IBM T.J. Watson Research Center. He was invited to the doctoral consortia of the International Conference on Information Systems in 1999 and the Academy of Management in 2000 and he has presented his work at various other conferences, including INFORMS, the Workshop on Information Systems and Economics, the Hawaii International Conference on Systems Sciences, the European Conference on Information Systems, the Sunbelt Social Network Analysis conference and the Strategic Management Society.
He is currently an assistant professor at the department of Decision and Information Sciences at the Rotterdam School of Management, Erasmus University. As a result of his research on electronic markets, his research interests branch out into areas within strategic management, entrepreneurship, behavioral decision theory and social network analysis.

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Information Architecture and Electronic Market Performance

Electronic markets are one of the most prominent business applications of the Internet, so determining the factors that drive their performance is of great value. This thesis shows that an important driver of electronic market performance is the information architecture of the market, which describes what type of information is available to whom during the market process. Two studies of electronic market initiatives at a large Dutch flower auction highlight how information and communication technology (ICT) affects the information architecture of the market and the consequences for market behavior. ICT not only affects existing markets, but also offers opportunities to design innovative new market mechanisms. One of these is a multidimensional auction, in which bidders bid not only on price, but also on dimensions such as quality and delivery time. The effects of different information architectures of multidimensional auctions are explored in laboratory experiments. The findings of the three studies are synthesized into a theory of electronic markets that has important implications for market designers, traders and researchers.

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