Auctions with competing sellers and behavioral bidders

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Voor mijn moeder

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When I was eight years old, my mom, sister, aunt and I visited Utrecht by train. Just a few weeks before, I had learned about networks in school and thus knew that Utrecht was the main hub of the Dutch railway network. I remember that my teacher hardly explained anything about networks, but instead warned us about the dangers of Utrecht. According to him, it was extremely busy and crowded with pickpockets. Being a little girl from a small village in Limburg, this made a big impression on me. It may therefore not be surprising that I was a bit anxious when I first exited the train in Utrecht. I was looking around nervously and clutching my bag (which contained nothing of value, I was a little girl after all), while telling my fellow travelers to do the same. Luckily my aunt, who lived in Sittard and was therefore the expert on 'big cities', calmed me down. The rest of the day was enjoyable, and I never again thought of Utrecht as scary or dangerous.

Now, many years later, I completed my PhD research at Utrecht University School of Economics (U.S.E.). Like my first arrival in Utrecht, the process of writing this dissertation was sometimes overwhelming. However, I look back on a journey that was exciting and filled with joy. This is in large part due to the fact that, just like that very first day in Utrecht, I have been surrounded by people who supported me, guided me through difficult times and, more generally, made the journey much more enjoyable. It is those people I would like to thank here. Without you, I would not have been able to complete the dissertation that is now in your hands.

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Joyce Delnoij
Utrecht, September 2016

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Chapter 1

Introduction

Auctions have a long and colorful history; they have been used to sell a wide variety of goods and services for at least 2500 years. The earliest account of auctions is given by the Greek historian Herodotus, who reports that around 500 B.C. Babylonian women were auctioned off for marriage. Later, auctions were used by the Romans to sell slaves, war booty and debtors' property, and by the Chinese to sell personal belongings of deceased Buddhist monks. Perhaps the most remarkable auction takes place in 193 A.D. After killing the emperor Pertinax, the Praetorian Guard announced that they would sell the entire Roman Empire by means of an auction. The highest bidder, Didius Julianus, was declared emperor. Unfortunately, Julianus' reign ended after only two short months, when he fell victim to an extreme form of what auction theorists now refer to as the winner's curse—he was beheaded.[1]

Over the course of history, the range of goods sold in auctions has grown tremendously. Art, antiques, real estate, cattle, fish, fruits, vegetables, and flowers are traditionally sold in auctions. Governments use auctions for the sale of Treasury bills, electricity distribution contracts, pollution permits and natural resources such as timber and mineral rights. Additionally, auctions are widely used in government procurement[2] and in the privatization of state-owned enterprises. In the past two decades, governments all over the world have organized auctions to allocate licenses for electromagnetic spectrum necessary for mobile communication. The volume of transactions

[1] A historical overview of auctioning is given by Cassady (1967).

[2] The process of procurement via competitive bidding is essentially an auction, where multiple sellers compete to sell a good or service to a single consumer. For simplicity, in this dissertation the perspective of an auction with one seller and many consumers will be adopted, but the theoretical and experimental results apply to procurement auctions as well.

and money involved in these auctions is unprecedented.[3]

Despite being widespread, auctions have never been the most common way of selling goods. Although auctions have the advantage of price discovery, they also suffer from high transaction costs (Ockenfels et al., 2006). As a result, auctions are only worthwhile when there is sufficient uncertainty about the value of the good for sale. With the rise of the Internet, however, both the costs and benefits of auctioning have changed. Whereas the costs of conducting and participating in an auction have declined, the opportunities for price discovery have risen due to an increase in the number of potential participants. In 1995, Onsale (later Yahoo) and eBay conducted the first auctions on the World Wide Web.[4] In recent years, a maturing market has seen the appearance of specialized online auction stores in which goods, for which well-established markets already exist, are also sold through a myriad of auctions. For example, in the Dutch online travel market several agencies offer holidays through auctions. Nowadays, online auctions are used to sell a wide variety of goods—from electronics and collector's items in online marketplaces to holidays and concert tickets in specialized online auction stores. An increasing amount of sellers and bidders find their way to auctions, both creating and created by an upsurge in media attention.[5]

Even though auctions have been conducted for several millennia, they have only been studied by economists in the past six decades. The seminal paper by Vickrey (1961), which analyzes auctions as games of incomplete information, has inspired an extensive and diverse literature. Auction theory is now one of the areas of economic theory that has been most successful in finding direct applications, but has traditionally focused on a monopolistic auctioneer selling a single good in a standard auction to a fixed number of fully rational bidders, who are solely concerned with maximizing monetary payoffs. Among others, auction theorists Paul Milgrom, Preston McAfee and Paul Klemperer have successfully advised governments on the design of auctions for the sale of electromagnetic spectrum to mobile phone operators. For auction theorists to be of equal use to online auctioneers, however, the traditional literature needs to be modified in at least three ways.

First, bidders in online auctions are hardly ever profit-maximizing businesses or professionals bidding for high-value goods. Instead, they are con-

[3]Experiences with and lessons learned from spectrum auctions can be found in Milgrom (2004) and Klemperer (2004).

[4]Auctions were already conducted online before the existence of the World Wide Web. Lucking-Reiley (2000) provides an overview of the early years of online auctioning.

[5]This is illustrated by the increasing popularity of TV shows about auctions and auctioneers, e.g., Auction Kings, Auction Hunters, American Pickers, Pawn Stars, and Storage Wars.

sumers bidding for (relatively) low-value goods, such as collectibles and holidays. Bidders may therefore not meet the assumptions posed in standard auction theory, but may be boundedly rational and/or have preferences beyond maximizing monetary payoffs. Experimental research has documented that bidders in various auction formats bid more than predicted by standard auction theory. Explanations for this phenomenon are based on the presence of non-standard preferences and, to a limited extent, bounded rationality or lack of experience. Besides overbidding, online auctions involve behavior such as jump bidding (e.g. Avery, 1998; Easley and Tenorio, 2004; Isaac et al., 2007) and last-minute bidding (Roth and Ockenfels, 2002; Bajari and Hortacsu, 2003, 2004; Ockenfels and Roth, 2006; Rasmusen, 2006), which may also be better explained by alternatives to standard auction theory.

Second, as online auctions are relatively inexpensive to conduct, have the potential of attracting many bidders and are free of geographical and time constraints, they provide an excellent opportunity to experiment with new design features and stopping rules. This has ultimately led to the development of new auction formats such as Buy-It-Now and pay-to-bid auctions. In the former, bidders can bid for a good but can additionally choose to end the auction by buying the good at a fixed, posted price.[6] The latter include penny auctions (e.g. Platt et al., 2013; Augenblick, 2016; Hinnosaar, 2016), price-reveal auctions (Gallice, 2016) and unique-bid auctions (e.g. Raviv and Virag, 2009; Östling et al., 2011; Radicchi et al., 2012).[7] These auctions are characterized by the use of bidding fees, very low winning bids, and intransparent bidding processes and ways of generating revenues. They are often criticized for their resemblance to gambling.[8] Next to this, online auctions may either have a fixed or flexible deadline and may last anywhere from a few minutes to several weeks. As a result, the auctions conducted on the Internet may be distinctively different from the so-called standard auctions studied by the traditional literature, which have in common that the bidder placing the highest bid wins the auction.

Third, a single good is frequently sold through multiple channels on the Internet. Consumers may either buy a good at a posted price or participate

[6]Tsuchihashi (2016) surveys the literature on Buy-It-Now auctions.

[7]A penny auction starts at a price of zero and ends after a period of time without new bids. Bidders must pay a fee to raises the price with one cent. The last bidder to place a bid wins the auctions and pays the final price. A price-reveal auction is a descending auction in which the current price is hidden and bidders have to pay a fee to reveal the price. In a unique-bid auction, bidders pay a fee to place a bid. The winner is the one who submitted the lowest or highest unique bid.

[8]The Betting and Gaming Authority (Kansspelautoriteit) in the Netherlands considers penny auctions as games of chance. The conduct of such auctions is therefore prohibited (Kansspelautoriteit, 2014).

in a wide variety of online auctions. This implies that online auctioneers are not monopolists. Instead, they operate in a competitive market. The presence of multiple auctioneers, who simultaneously sell units of a homogeneous good in a possibly diverse set of auctions, allows bidders to choose not only between auctioneers but even between auction formats. The number of bidders in an online auction is therefore not fixed but the outcome of an endogenous entry process. A bidder's decision to enter a certain auction in favor of another may be based on her personal preferences but may also be the result of entry coordination. That is, an auction that is as such preferred, may no longer be preferred if it is attracting many competing bidders who drive up the price. When deciding which auction to offer, an online auctioneer should therefore consider bidders' preferences, as well as the auctions his competitors offer.

Summing up, to account for recent developments in the field of auctions, auction theorists may extend standard auction theory by considering that bidders may have non-standard preferences, that they endogenously enter competing auctions, and that these may include non-standard auctions. The contributions in this dissertation revolve around these three departures from the traditional literature. The dissertation begins by studying endogenous entry and competing auctions. Chapter 2 theoretically investigates which auctions—first-price or second-price—are selected by competing auctioneers when risk averse bidders endogenously enter auctions. Chapter 3 continues to study entry into auctions, but considers a set of empirically relevant selling mechanisms and a broader range of preferences. By means of an exploratory experiment, it analyzes bidders' decisions between participating in an auction with or without a Buy-It-Now option and buying at a posted price. In this way, this dissertation does not only contribute to the advancement of the theory of endogenous entry and competing auctions, but also to an understanding of the various motivations underlying bidders' entry decisions. Finally, Chapter 4 theoretically studies how bidding behavior in first-price and second-price auctions is affected by the presence of social competition and, in particular, social comparison concerns.

The remainder of this introductory chapter is constructed as follows. Section 1.1 contains a broad overview of the theoretical and experimental literature on auctions. As the literature is both extensive and diverse, this overview is limited to the main theories and experimental results guiding the research in this dissertation. Section 1.2 provides a general outline of the chapters' research questions and methodologies, and Section 1.3 provides some final remarks about the setup of the dissertation.

1.1 A short guide to auction theory

The treatment of auctions in the economics literature is fairly recent. The first game-theoretic analysis of auctions was by Vickrey (1961), but the topic was only picked up by other economists at end of the 1970s. Ever since, the literature has been quickly expanding into many different directions. This section introduces the basic concepts, as well as some of the most important insights of auction theory.

Since many selling mechanisms are classified as auctions, it is not easy to give a precise definition of what constitutes an auction. According to Krishna (2010), auctions elicit information about bidders' willingness to pay for a certain good. The allocation of this good typically depends on the revealed information. Krishna also points out that auctions are both universal, i.e., they can be used to sell any good, and anonymous, i.e., the identities of bidders play no role in determining the allocation of the good.

The traditional literature focuses on four auction formats: English, Dutch, first-price and second-price auctions. Whereas the first two are open auctions in which bids are publicly observable, the latter are sealed-bid auctions. The English auction is an ascending auction, which is typically used for art objects. The auctioneer starts at a low price and successively calls higher prices until only one bidder remains. In contrast, the Dutch auction is a descending auction, which is most famously used to sell flowers in the Netherlands. The auctioneer initially calls a high price and then gradually lowers this price until one bidder indicates that she is willing to buy the good. In the first-price and second-price auction, each bidder submits a single bid without observing the bids of others and the bidder with the highest bid wins. Whereas the winning bidder pays her own bid in the first-price auction, she pays the second-highest bid in the second-price auction. The literature on auctions further makes a distinction between single-unit and multi-unit auctions. When multiple units of a homogeneous good are sold, auctioneers may sell these units separately in multiple auctions or jointly in a single auction.

A key feature of auctions is the presence of incomplete information. This implies that the seller is uncertain about the bidders' values (willingness to pay) of the good for sale. If the seller would know these values with certainty, he could simply sell the good at a posted price to the bidder with the highest value. Auction models typically fall into two categories. The private value model assumes that bidders know only their own value with certainty. Furthermore, this value does not depend on the values of other bidders. In contrast, the interdependent value model assumes that bidders only have partial information about the value of the good. Bidders have private estimates about this value and these estimates may be affected by the estimates of other bidders. A special case of the interdependent value model is the pure common value model, which assumes that all bidders attach the same value to a good but do not know this value at the time of bidding. A typical example of such a good is an oil field. When it comes to the distribution of private and interdependent values, the literature assumes that the distribution is either independent or affiliated (correlated), and either symmetric or asymmetric.

The most widely used model in the literature on auctions is the symmetric independent private value model as introduced by Vickrey (1961). This model, also referred to as standard auction theory, can be applied to any situation where a seller offers a single unit of a good to a group of $N \geq 2$ bidders. The key assumption of this model is that each bidder's private value v_i is independently and identically distributed according to a common distribution function $F(v)$, with strictly positive density $f(v)$ on the interval $[\underline{v}, \overline{v}]$. Furthermore, the number of bidders is fixed, and bidders are risk neutral and not limited by any budget constraints, i.e., they are able to pay up to their respective values.

Without a doubt, the most influential result in auction theory is the revenue equivalence theorem, which states that, under the assumptions of the symmetric independent private value model, all standard auctions generate the same expected revenue. This result was first shown for the English, Dutch, first-price and second-price auction by Vickrey (1961), and was later generalized to all standard auctions by Myerson (1981) and Riley and Samuelson (1981). To get an intuition for the revenue equivalence theorem, let us take a look at the bidding strategies in the English, Dutch, first-price and second-price auctions.

The first-price and Dutch auction are strategically equivalent, as in these auctions each bidder must choose how much to bid without knowing the decisions of others. The payoff to the winning bidder is equal to her value minus her own bid; the payoff to losing bidders is zero. As a result, bidders will never bid as much as their own values, as this will generate a payoff of zero. Instead, bidders adjust their bids downwards. It can be shown that each bidder maximizes her expected payoff by bidding an amount equal to the expectation of the highest of $N-1$ values below her own value v or, in other words, the second-highest value. That is, the symmetric Bayesian Nash equilibrium bidding strategy for risk neutral bidders, commonly referred to as the Risk Neutral Nash Equilibrium (RNNE), in the first-price (and Dutch) auction is given by

$$b^{FPA}(v) = v - \int_{\underline{v}}^{v} \left(\frac{F(t)}{F(v)} \right)^{N-1} dt$$

The expected revenue of the first-price and Dutch auction is therefore equal to the expectation of the second-highest value.

In the second-price auction, the payoff to the winning bidder is her value minus the second-highest bid; the payoff to losing bidders is again zero. This is the same in the English auction, as then the winning bidder pays the price at which the one-but-last bidder has left the auction. In these auctions, each bidder has a weakly dominant strategy to bid her own private value. That is, the RNNE in second-price (and English) auctions is given by

$$b^{SPA}(v) = v$$

If a bidder bids less than her own value, she sacrifices an opportunity to win while receiving a positive payoff. However, if she bids more than her own value, this only increases the probability that she wins at a price above her own value and receives a negative payoff. Given that all bidders bid truthfully, i.e., bid their own value, the expected revenue in the second-price and English auction is also equal to the expectation of the second-highest value.

Ever since the emergence of experimental economics, a large experimental literature on auctions has developed.[9] Auction theory provides the basis for experimental testing, which in turn reveals behavior that inspires the development of new theories. A majority of experiments focus on the symmetric independent private value model, e.g., testing the revenue equivalence theorem. In such experiments, bidders typically participate in a number of auction rounds, in which they bid for a fictitious good. In each round, each bidder receives a value that is randomly drawn from a commonly known distribution. Contrary to theoretical predictions, experiments find no evidence for revenue equivalence.[10] Instead, they find that bidders in both first-price and second-price auctions bid more than predicted by theory (e.g. Cox et al., 1985, 1988; Kagel et al., 1987; Kagel and Levin, 1993). The literature attempts to explain this phenomenon named overbidding by relaxing the assumptions of the symmetric independent private value model, and in particular by introducing non-standard preferences.

The leading theory explaining overbidding in first-price auctions refers to relaxing the assumption of risk neutrality. Various studies have shown that increasing the bid of a risk averse bidder leads to a utility gain from the increase in the probability of winning the auction that is greater than the cost of paying a higher price (e.g. Riley and Samuelson, 1981; Maskin and

[9] Svorenčík (2015) points out that the experiments on auctions, and the first-price auction in particular, have played a major role in the acceptance of experimentation in economics.

[10] For an extensive overview of the experimental literature on auctions, see Kagel (1995) and Kagel and Levin (2014).

Riley, 1984; Cox et al., 1985, 1988). Intuitively, by bidding higher, a risk averse bidder insures herself against the possibility of losing the first-price auction. In second-price auctions, however, risk averse bidders still have a weakly dominant strategy to bid truthfully. As a result, the first-price auction generates higher expected revenues than the second-price auction if bidders are risk averse. Several other adaptations of the symmetric independent private value model have been suggested to explain overbidding, e.g., ambiguity aversion, regret aversion, joy of winning, fear of losing, spite and reference-dependent preferences. To this day, there is no consensus on which of these adaptations best explains the experimental and empirical evidence.[11]

Another line of research that has been actively pursued by theorists and experimentalists modifies the symmetric independent private value model by relaxing the assumption that the number of bidders in an auction is fixed. Instead, it is assumed that bidders endogenously enter auctions. The theoretical literature on entry into auctions has so far focused on the decision whether or not to enter an auction, in the presence of either an entry fee or an outside option (e.g. McAfee and McMillan, 1987b; Levin and Smith, 1994; Smith and Levin, 1996; Menezes and Monteiro, 2000; Pevnitskaya, 2004). The experimental literature has also studied bidders' entry decisions between competing auction formats, for instance, between first-price and English auctions (e.g. Ivanova-Stenzel and Salmon, 2004a,b, 2008a,b, 2011; Engelbrecht-Wiggans and Katok, 2005). However, a theoretical framework on entry between competing auctions, or research on entry between non-standard auctions, is currently missing.[12]

1.2 Outline of the dissertation

This dissertation considers departures from the symmetric independent private value model related to the presence of competing sellers and behavioral bidders. In three separate chapters, various aspects of non-standard preferences, non-standard auctions and endogenous entry in auctions are studied. In doing so, the research in this dissertation combines the tools of game theory and experimental methods. This section introduces the different chapters and the research questions and methods addressed in them.

[11] A more complete overview of the literature on overbidding in auctions can be found in Section 4.2.

[12] Section 2.1 reviews the literature on bidder preferences and endogenous entry in further detail. Extensive overviews of the literature on entry into auctions can be found in Kagel and Levin (2014) and Aycinena et al. (2015).

Chapter 2 studies endogenous entry into competing auctions. On the Internet, units of a homogeneous good are sold in numerous simultaneous auctions, allowing bidders to choose which auction to enter. As a result, auctioneers compete against one another to attract bidders, and should be strategic when deciding which auction to offer. Hence, this chapter attempts to answer the following research question: Which auctions are selected by competing auctioneers when bidders endogenously enter auctions? To answer this question, the existing models of endogenous entry into auctions need to be adjusted such that bidders may choose not simply between entering an auction or not, but between entering one auction versus an alternative auction. An auction selection game consisting of three stages is constructed, in which multiple units of a homogenous good are simultaneously offered in separate auctions to a group of N bidders. At Stage 1, sellers decide which auctions to offer. At Stage 2, the bidders learn which auctions have been selected and enter one of them. At Stage 3, the auctions are conducted. Building cumulatively on the existing literature on bidder preferences and endogenous entry into auctions (e.g. Matthews, 1987; Levin and Smith, 1994; Smith and Levin, 1996; Pevnitskaya, 2004), our model considers risk neutral sellers, who may offer their goods in either first-price or second-price auctions. Bidders are assumed to be homogeneously risk averse and only learn their private value for the good once they have entered an auction. This implies that bidders cannot make their entry decisions dependent on any private information they may have. For this reason, the entry decision at Stage 2 of the game is modeled as a symmetric equilibrium involving mixed strategies. Chapter 2 does not only add to the literature on endogenous entry into auctions, but also allows us to better compare the profitability of different auctions and thereby contributes to existing revenue ranking results.

Chapter 3 furthers the study of endogenous entry by looking at non-standard auctions and non-standard preferences. More specifically, it analyzes entry decisions over three selling mechanisms that are frequently used on the Internet: ascending auction, Buy-It-Now auction and posted price. Which selling mechanism is preferred by consumers? Can these preferences be explained by differences in expected payoffs across mechanisms (monetary incentives), or do consumer characteristics (non-monetary incentives) also play a role? To answer these questions, Chapter 3 employs an experimental approach. The experiment, which builds on the studies by Ivanova-Stenzel and Salmon (2004a,b, 2008a,b, 2011), involves subjects making a series of entry decisions between three pairs of selling mechanisms. Subjects choose between posted price and ascending auction, between posted price and Buy-It-Now auction, and between Buy-It-Now auction and ascending auction. To maximize external validity, the selling mechanisms in the experiment are modeled after those found on the Internet, meaning that subjects are required to place bids themselves and that there is a fixed deadline.[13] The Buy-It-Now option is permanently available and the first subject to select this option wins the good with certainty. In contrast to Chapter 2, subjects in the experiment are informed about their values and about the Buy-It-Now price before making their entry decisions. The role of monetary incentives in entry decisions is measured by the expected payoffs of buying versus bidding. Furthermore, a number of psychometric measures is included in the experiment, which together constitute the non-monetary incentives. These measures involve a risk attitude elicitation task, a loss attitude elicitation task, and a questionnaire measuring impatience, sensation seeking and regret. Doing so allows us to get a better understanding of how consumers choose between different selling mechanisms.

Chapter 4 considers a set of non-standard preferences that have so far been ignored in the literature on auctions: social comparison concerns. Social psychologists have argued that the tendency to compare ourselves to others may generate competitive behavior. Auctioneers and auction theorists alike have argued that the presence of social competition is one of the main drivers of the success of auctions. For instance, Ockenfels et al. (2006) argue that bidders enjoy auctions because of the thrill of competing against others and Fliessbach et al. (2007) suggest this is due to a drive to outperform others. Chapter 4 therefore addresses the following research question: How do social comparison concerns affect bidding behavior in first-price and second-price auctions? To answer this question, a model of interdependent preferences is adopted. In this model the bidder's utility function consists of two additive components: a monetary and a social component. Monetary utility is a function of the bidder's own payoff; social utility is a function of the difference in payoffs between the bidder and the competing bidders. Our model assumes that bidders derive utility from being better off than others, i.e., they experience pride. Conversely, bidders derive disutility from being worse off than others, i.e., they experience envy. In this way, Chapter 4 explores social comparison concerns as an explanation for the overbidding observed in experiments.

Finally, Chapter 5 provides a general interpretation of the results from the preceding chapters and additionally offers suggestions for further research.

[13]For this reason, ascending auctions conducted on the Internet may be very different from the English auction described in Section 1.1 and may involve behavior such as jump bidding and last-minute bidding. Throughout the dissertation, the term 'ascending auction' refers to those ascending auctions found online.

1.3 Remarks

Before proceeding with the remaining chapters, some final remarks are in order. Chapters 2 to 4 of this dissertation were written as independent research papers. Each chapter is therefore self-contained, consisting of separate introductions and conclusions, and introducing the relevant terminology and notation independently. Any reader who wishes to read only some chapters of the dissertation, or wishes to read them in a different order, may do so. However, it should be pointed out that there may be some overlap between the different chapters, as well as the general introduction and conclusion. The terminology and notation are kept as uniform as possible across chapters, but slight differences may occur. Some proofs are relegated to appendices at the end of the dissertation.

The reader may notice that throughout this dissertation different pronouns are used to refer to certain economic agents. Whereas 'she' is used for bidders, consumers or subjects, 'he' is used for auctioneers or sellers. The sole reason for doing so is to clarify the reading, as the use of different pronouns removes ambiguities.

Finally, this dissertation reflects the knowledge I gained during the course of my PhD, but as such also reflects the expertise present at Utrecht University School of Economics and at the online auction company Emesa. Chapter 2 is joint work with Kris De Jaegher and Chapter 3 is joint work with Kris De Jaegher and Stephanie Rosenkranz. This dissertation greatly benefitted from insights provided by Emesa, as they helped me shape the experiment in Chapter 3 and were a great source of inspiration in identifying the research lines of endogenous entry and social comparison concerns.

Chapter 2

Competing first-price and second-price auctions*

2.1 Introduction

The use of auctions as a means of selling goods has traditionally been confined to specific goods such as art objects and agricultural products. The rise of the Internet, however, has led to a reduction in transaction costs and better matching of supply and demand, and has thereby created new markets for auctions (Ockenfels et al., 2006). Nowadays, a vast volume of economic transactions is conducted through online auctions. Online marketplaces, like eBay and Yahoo, offer a multitude of simultaneous auctions in which goods such as collectibles and phones are sold; specialized online auction stores sell goods for which well-established markets already exist such as holidays, concert tickets and computers. The development that units of a homogeneous good are now sold through multiple auction formats allows consumers to choose which mechanism to enter. As a result, auctioneers find themselves competing against one another to attract consumers.

The economics literature has long treated auctions as isolated, studying how a single seller facing multiple bidders can maximize his revenue or, in the case of procurement auctions, how a single bidder facing multiple sellers can maximize her utility. Auction theory's most celebrated results, the revenue ranking theorems, compare the expected revenues of different auction formats while treating the number of bidders in each auction as given (e.g. Vickrey, 1961; Myerson, 1981; Riley and Samuelson, 1981; Maskin and Riley, 1984). Though these results have proven to be very valuable for the design of auctions for isolated sales such as the spectrum auctions, the tradi-

*The study presented in this chapter is joint work with Kris De Jaegher.

tional revenue ranking theorems may no longer apply if auctioneers operate in a competitive market, where the ability to attract bidders is a crucial determinant of an auction's success (e.g. Klemperer, 2002; Ivanova-Stenzel and Salmon, 2008a). After all, an auction that in isolation generates the highest revenue may no longer do so if bidders have no incentive to enter this auction. "In practice, auctions [...] often fail because of insufficient interest by bidders" (Milgrom, 2004, p.209). An auctioneer operating in a competitive market should therefore consider bidders' preferences, as well as the selling mechanisms his competitors offer, when deciding which auction to offer.

The aim of this chapter is to study the auction selection problem of competing auctioneers. That is, we theoretically investigate which auctions are selected by auctioneers when they operate in a competitive market and when bidders endogenously enter auctions. In doing so, we consider an auction selection game consisting of three stages. At Stage 1 of the game, sellers decide which auctions to offer. At Stage 2, the bidders learn which auctions are offered and enter one of them. At Stage 3, the auctions are conducted.

Throughout this chapter, we make the following modeling assumptions on sellers. We consider risk neutral sellers who simultaneously offer a single unit of a homogeneous good in sealed bid auctions. More precisely, sellers may choose to offer a first-price auction or a second-price auction. These auctions and their dynamic counterparts (the Dutch and English auction, respectively) are frequently used both on and off the Internet and have, for that reason, also attracted considerable attention in the theoretical and experimental literature. In the main analysis we restrict the number of sellers to two, but we later show that qualitatively similar results can be obtained when there are more than two sellers.

On the bidders' side, we assume that bidders demand one unit of the good and choose to enter one of the auctions. They cannot choose to opt out of the auction or enter both auctions instead. Additionally, the bidders are ex ante symmetrically informed. This means that before entering an auction bidders do not know their own value for the good, which is both independent and private, but they do know the distribution of values.[1] Fur-

[1]This is a common assumption in much of the theoretical and experimental literature studying entry into auctions (e.g. McAfee and McMillan, 1987b; Engelbrecht-Wiggans, 1987, 1993; Levin and Smith, 1994; Smith and Levin, 1996; Pevnitskaya, 2004; Palfrey and Pevnitskaya, 2008; Ivanova-Stenzel and Salmon, 2004a,b, 2008a,b). The assumption is motivated by examples where bidders may only learn their exact value for the good for sale once they actually participate in the auction. Pevnitskaya (2004) gives an example of antique auctions, where sellers often advertise general inventory and where bidders can determine their exact value only after coming to the auction house and examining the goods prior to sale. As a result, these bidders do know the distribution of values, but

thermore, bidders know whether and to which extent they are risk averse, but in the main analysis we assume that bidders are homogeneous in this respect. This implies that bidders cannot make their entry decisions dependent on any private information they may have. In an extension, however, we discuss the implications of allowing bidders to be heterogeneously risk averse.

Various studies have analyzed the role of risk aversion in auctions and have shown that it is a critical factor explaining why bidders may not be indifferent between various auction formats. Theoretical research predicts that risk aversion results in overbidding in first-price auctions but does not change the equilibrium bidding strategy in second-price auctions (e.g. Riley and Samuelson, 1981; Maskin and Riley, 1984; Cox et al., 1985, 1988). As such, it also affects the utility bidders can expect from participating in these auctions (Matthews, 1983, 1987). Previous experimental studies have shown that risk aversion may play a role in bidders' entry decisions between different auctions, although the results are contingent on the experimental design.[2] Our study aims to provide the theoretical foundations for these findings and additionally explores the implications for the auction selection problem of competing auctioneers.

The auction selection game is solved using backward induction. We use existing results on bidding strategies and bidder preferences among auctions to analyze bidders' entry decisions in Stage 2. In doing so, we extend the models of endogenous entry of Levin and Smith (1994), Smith and Levin (1996) and Pevnitskaya (2004), who model entry as a symmetric equilibrium involving mixed strategies. We find that the probability of entering each auction depends on the bidders' degree of absolute risk aversion. More specifically, when bidders decide between entering a first-price and a second-price auction, each auction is entered with equal probability if bidders are risk neutral or exhibit constant absolute risk aversion. However, if bidders exhibit decreasing absolute risk aversion, they are more likely to enter the second-price auction; if bidders exhibit increasing absolute risk aversion, they are more likely to enter the first-price auction. As risk averse bidders overbid in first-price auctions but not in second-price auctions, these findings imply that in Stage 1 both sellers prefer to offer first-price auctions when bidders exhibit nondecreasing absolute risk aversion. However, when bidders exhibit decreasing risk aversion, other auction selection equilibria

only know their independent private value after entering the auction.

[2]Ivanova-Stenzel and Salmon (2004a, 2008b) find that risk aversion explains entry decisions between English and first-price auctions when each auction consists of only two bidders. In another set of experiments, the authors allow bidders to coordinate freely over the auctions (Ivanova-Stenzel and Salmon, 2008a, 2011). In these circumstances, risk aversion does not seem to explain entry decisions.

may exist.

Our study adds to the literature on bidder preferences and endogenous entry, as well as to the literature on competing auctions. Whereas auction theorists have traditionally focused on the seller's perspective, researchers are now also taking the bidder's point of view. It can be seen that Myerson's (1981) proof for the revenue equivalence between first-price and second-price auctions follows from a utility equivalence for risk neutral bidders. Risk neutral bidders are thus indifferent between first-price and second-price auctions. Matthews (1983, 1987) compares the utility of bidders with different degrees of absolute risk aversion. He finds that bidders who exhibit constant absolute risk aversion are also indifferent between first-price and second-price auctions. This result is later generalized by Monderer and Tennenholtz (2004) for all k-price auctions and by Hon-Snir (2005) for all standard auctions.[3] Hon-Snir additionally shows that the utility equivalence for risk averse bidders holds if and only if bidders exhibit constant absolute risk aversion. This is consistent with the findings of Matthews (1987), who shows that bidders with decreasing absolute risk aversion prefer second-price auctions and bidders with increasing absolute risk aversion prefer first-price auctions.

The theoretical literature on entry into auctions studies the decision whether or not to enter an auction with an entry fee or when there exists an outside option. The literature can roughly be divided into two strands. The first strand assumes that bidders do not possess any private information before deciding to enter an auction or not. In this case, the theoretical literature focuses on two types of equilibria. McAfee and McMillan (1987b) and Engelbrecht-Wiggans (1987, 1993) focus on deterministic, asymmetric equilibria involving pure entry strategies. This approach results in a plethora of equilibria, where a subset of bidders enters the auction and another subset does not. The process by which symmetric bidders are divided into these subsets, however, is not identified. Levin and Smith (1994) and Smith and Levin (1996) therefore focus on a unique, stochastic, symmetric equilibrium involving mixed entry strategies. Various experimental and empirical studies have compared these two approaches and find that entry is best explained by the stochastic model (e.g. Smith and Levin, 2002; Bajari and Hortacsu, 2003; Reiley, 2005). The second strand of the literature assumes that bidders obtain some type of private information before making their entry decisions. This includes bidders' private values (Menezes and Monteiro, 2000) and bidders' heterogeneous degrees of risk aversion (Pevnitskaya, 2004; Palfrey and Pevnitskaya, 2008). These stud-

[3] A standard auction is defined as an auction in which the bidder with the highest bid wins.

ies find that there is a unique entry equilibrium in pure strategies, which involves a cut-off value based on the bidders' private information. To the best of our knowledge, our study is the first to develop a theoretical model on entry decisions between different auction formats, although some experimental studies on this topic exist (e.g. Ivanova-Stenzel and Salmon, 2004a,b, 2008a,b, 2011; Engelbrecht-Wiggans and Katok, 2005).[4]

Most studies in the competing auctions literature analyze auction selection problems where the dimension along which sellers compete is the reserve price or the entry fee (e.g. McAfee, 1993; Peters and Severinov, 1997; Damianov, 2012). Instead, the dimension along which sellers compete in our study is the auction format itself. The study that is perhaps most closely related to ours is that of Monderer and Tennenholtz (2004), who theoretically investigate auction selection with bidders who exhibit constant absolute risk attitudes but assume exogenous random participation (McAfee and McMillan, 1987a). They find that sellers prefer to select a first-price auction when bidders exhibit constant absolute risk aversion. When bidders exhibit constant absolute risk seekingness, however, sellers will be better off selecting a k-price auction of higher order. Including a larger range of risk attitudes and assuming entry to be stochastic, allows us to obtain novel insights into auction selection and simultaneously add to existing revenue ranking results.

The remainder of this chapter is structured as follows. Section 2.2 describes the model in detail. Section 2.3 analyzes the entry decisions in Stage 2 of our three-stage game and Section 2.4 analyzes the auction selection in Stage 1. Finally, Section 2.5 discusses some extensions of our model, and Section 3.5 discusses our findings and provides concluding remarks.

2.2 Model

Suppose that two sellers simultaneously offer a single unit of a homogeneous good to a group of $N \geq 2$ bidders. Each seller decides to offer the good either in a first-price auction (FPA) or in a second-price auction (SPA); bidders are free to enter either auction. We assume that sellers are risk neutral and have zero value for the good. Bidders are symmetric and homogeneous. More specifically, bidder i's preferences are given by the utility function $u(m_i)$, which satisfies $u'(m_i) > 0$ and $u''(m_i) \leq 0$, and where m_i represents her payoff. Throughout this chapter, we use r to refer to the Arrow-Pratt coefficient of absolute risk aversion, which is measured by $-\frac{u''(m_i)}{u'(m_i)}$.

[4] Extensive overviews of the literature on entry into auctions can be found in Kagel and Levin (2014) and Aycinena et al. (2015).

We consider the following three-stage game, which is an extension of the models of endogenous entry by Levin and Smith (1994), Smith and Levin (1996), and Pevnitskaya (2004). At Stage 1, seller $l = \{1, 2\}$ selects auction $a_l = \{FPA, SPA\}$. At this stage, the number of bidders, N, their utility functions, $u(m_i)$, and the distribution of values, $F(v)$, are common knowledge. Prior to Stage 2, the N bidders learn a_l, i.e., they learn which auctions have been selected by the sellers. Subsequently, each of the N bidders enters one of the auctions: n_1 bidders enter a_1 and $n_2 = N - n_1$ bidders enter a_2. At Stage 3, the auctions are conducted. Each bidder i learns n_l and receives her private value v_i, which is independently and identically distributed according to the common distribution function $F(v)$, with strictly positive density $f(v)$ on the interval $[\underline{v}, \overline{v}]$. All bidders then simultaneously submit sealed bids according to the unique, symmetric and increasing Bayesian Nash equilibrium bidding function $b(v|a_l, n_l)$. The outcome of the auctions is to allocate the goods to the highest bidders. If bidder i wins the auction, she receives a payoff of $v_i - p_i$, where p_i represents i's payment. Whereas in the FPA p_i is equal to i's own bid, in the SPA it is equal to the bid of the second highest bidder. If bidder i does not win the auction, she receives a payoff of zero.

The outcomes of Stage 3 have been extensively analyzed in the literature (e.g. Vickrey, 1961; Riley and Samuelson, 1981; Maskin and Riley, 1984). In the FPA, the equilibrium bidding strategy when bidders are risk neutral is to bid an amount equal to the expectation of the highest of $n_l - 1$ values below one's own value. When bidders are risk averse, however, the equilibrium bidding strategy is higher. In the SPA, the equilibrium bidding strategy is to bid one's own value, regardless of whether bidders are risk averse or not. Applying backward induction, we use these outcomes to analyze the entry decisions in Stage 2 and the selection of auctions in Stage 1.

2.3 Endogenous entry

In this section, we analyze bidders' entry decisions in Stage 2 of the game. Let $E[u|a_l, n_l]$ denote each bidder's ex ante expected utility from entering auction a_l, learning n_l and, after learning her value v, bidding according to the symmetric equilibrium bidding strategy $b(v|a_l, n_l)$. Note that $E[u|a_l, n_l]$ is decreasing in n_l, because an increase in the number of bidders decreases the probability of winning and raises the payment in both FPA and SPA (Smith and Levin, 1996). Moreover, if a bidder is the only one in an auction, she will earn a positive payoff with certainty.

Following Levin and Smith (1994), Smith and Levin (1996) and Pevnitskaya (2004), we focus on a symmetric entry equilibrium. Any symmetric entry equilibrium will necessarily involve mixed strategies, such that each bidder enters a_1 with probability q^* and enters a_2 with probability $1-q^*$.[5,6] The reason for this is simple. Suppose that all bidders enter a_1. Then each bidder has an incentive to switch to a_2, as in this auction she will be the only bidder and thereby earn a positive payoff with certainty. The same holds if all bidders enter a_2. In equilibrium, each bidder must therefore be indifferent between entering a_1 and a_2. This implies that the symmetric entry equilibrium, given by $q^* \in (0,1)$, is described by

$$\sum_{n_1=1}^{N} \binom{N-1}{n_1-1} (q^*)^{n_1-1}(1-q^*)^{N-n_1} E[u|a_1,n_1]$$
$$= \sum_{n_2=1}^{N} \binom{N-1}{n_2-1} (1-q^*)^{n_2-1}(q^*)^{N-n_2} E[u|a_2,n_2] \qquad (2.1)$$

where the left-hand side (LHS) of (2.1) gives the expected utility of entering a_1 and the right-hand side (RHS) gives the expected utility of entering a_2. Furthermore, the terms in the brackets give the binomial probability that exactly $n_l - 1$ competing bidders also enter the auction, giving n_l in total. We find that the resulting equilibrium probability of entry is unique for a given r.

Lemma 2.1 *There exists a symmetric entry equilibrium in mixed strategies, such that each bidder enters auction a_1 with probability q^* and enters auction a_2 with probability $1-q^*$. The equilibrium probability of entry is implicitly defined by* (2.1) *and is unique for a given risk parameter r.*

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[5] Note that the actual number of bidders in a_1 then follows a binomial distribution with mean $q^*N = \overline{n}_1$ and variance $(1-q^*)\overline{n}_1$. Similarly, the actual number of bidders in a_2 follows a binomial distribution with mean $(1-q^*)N = \overline{n}_2$ and and variance $q^*\overline{n}_2$.

[6] Even with symmetric bidders asymmetric entry equilibria may exist, where some subset of bidders enters a_l with probability 1 and another subset enters $a_{\neg l}$ with probability 1. Likewise, asymmetric equilibria may exist where some subset of bidders enters a_l with probability 1 and where another subset of bidders randomizes over the auctions with the symmetric entry probability q. However, note that it is not possible to have asymmetric equilibria where different bidders have different mixing probabilities, as (2.1) is identical for all bidders. Furthermore, note that the assumption of pure strategies may lead to very many equilibria, dependent on which subset of bidders enters a_l and which subset enters $a_{\neg l}$. This creates an equilibrium selection problem. Therefore, we solely focus on a symmetric entry equilibrium, which not only restores full symmetry to the model but also turns out to be unique.

Proof. Define $z(q,r)$ as the function equal to the LHS minus the RHS of (2.1). From Lemma 1 of Pevnitskaya (2004, p.6), it immediately follows that the LHS of (2.1) is continuous and monotonically decreasing in q. The RHS of (2.1) is continuous and monotonically increasing in q (see Lemma A.1 in Appendix A.1). This implies that $z(q,r)$ is continuous and monotonically decreasing in q.

Equilibrium is achieved when $z(q^*,r) = 0$. Notice that any q^* satisfying this condition must be in the interval $(0,1)$. For instance, suppose that $q^* = 0$, such that all bidders enter a_2. Then $z(q^*,r) > 0$ and each bidder can receive a positive payoff with certainty by entering a_1. Conversely, suppose that $q^* = 1$, such that all bidders enter a_1. Then $z(q^*,r) < 0$ and each bidder can receive a positive payoff with certainty by entering a_2. As a result, only $0 < q^* < 1$ can satisfy $z(q^*,r) = 0$. By the intermediate value theorem it then follows that there exists a unique symmetric equilibrium probability of entry, q^*, and it is defined by (2.1). □

The value of the equilibrium probability of entry, q^*, crucially depends on the type of auctions that are selected by the sellers and on the utility functions of the bidders. Lemma 2.2 and Proposition 2.1 give q^* for different circumstances.

Lemma 2.2 *Suppose that either $a_1 = a_2$, or $a_1 \neq a_2$ and bidders are risk neutral ($r = 0$). The symmetric entry equilibrium is then given by $q^* = 0.5$.*

Proof. Let $a_1 = a_2$. It follows immediately that $E[u|a_1,n_1] = E[u|a_2,n_2]$ for $n_1 = n_2$. Similarly, let $a_1 \neq a_2$ and $r = 0$. From the utility equivalence principle for risk neutral bidders, that follows from Myerson (1981), we know that $E[u|a_1,n_1] = E[u|a_2,n_2]$ for $n_1 = n_2$. As a result, each bidder's entry decision is only affected by the number of competing bidders in each auction. This leads bidders to randomize over auctions with equal probability, that is, $q^* = 0.5$. □

When both sellers select FPAs or, equivalently, SPAs, then the ex ante expected utility of a_1 and a_2 is the same whenever the number of bidders in each auction is also the same. This implies that bidders are indifferent between entering a_1 and a_2 as long as $n_1 = n_2$. In equilibrium, bidders will therefore enter each auction with equal probability. When sellers select different auctions, such that bidders may choose between entering a FPA and a SPA, and bidders are risk neutral, then bidders will enter each auction with equal probability as well. When bidders are risk averse, however, the equilibrium probability of entry depends on the bidders' degree of absolute risk aversion. We distinguish between constant absolute risk aversion ($\partial r/\partial m_i = 0$), decreasing absolute risk aversion ($\partial r/\partial m_i < 0$), and increasing absolute risk aversion ($\partial r/\partial m_i > 0$).

Proposition 2.1 *Suppose that seller 1 selects a first-price auction ($a_1 = FPA$) and seller 2 selects a second-price auction ($a_2 = SPA$), and that bidders are risk averse ($r > 0$). The symmetric entry equilibrium is then given by*

(i) $q^* = 0.5$, *if bidders exhibit constant absolute risk aversion (CARA)*
(ii) $q^* < 0.5$, *if bidders exhibit decreasing absolute risk aversion (DARA)*
(iii) $q^* > 0.5$, *if bidders exhibit increasing absolute risk aversion (IARA)*

where q^* defines the equilibrium probability of entering the first-price auction and $1 - q^*$ defines the equilibrium probability of entering the second-price auction.

Proof. The proof of Proposition 2.1 consists of two steps. Recall that the value of q^* that satisfies $z(q^*, r) = 0$ characterizes the symmetric equilibrium. In Step 1, we show that if each auction is entered with equal probability ($q = 0.5$) then $z(0.5, r)$ is equal to zero if bidders exhibit CARA, is negative if bidders exhibit DARA, and is positive if bidders exhibit IARA. In Step 2 of the proof, we demonstrate how q needs to be adjusted such that the equilibrium condition is satisfied.

Step 1: Suppose that $r > 0$ and that $q = 0.5$. From Theorem 1 of Matthews (1987, p.638) it then follows that, for $n_1 = n_2$, the ex ante expected utility in each auction is

(i) $E[u|FPA, n_1] = E[u|SPA, n_2]$, if bidders exhibit CARA
(ii) $E[u|FPA, n_1] < E[u|SPA, n_2]$, if bidders exhibit DARA
(iii) $E[u|FPA, n_1] > E[u|SPA, n_2]$, if bidders exhibit IARA

This implies that, for a given $q = 0.5$, the LHS of (2.1) is equal to the RHS if bidders exhibit CARA, is smaller than the RHS if bidders exhibit DARA, and is larger than the RHS if bidders exhibit IARA. Hence,

(i) $z(0.5, r) = 0$, if bidders exhibit CARA
(ii) $z(0.5, r) < 0$, if bidders exhibit DARA
(iii) $z(0.5, r) > 0$, if bidders exhibit IARA

Step 2: (i) of Proposition 2.1 follows immediately from Lemma 2.1. What follows here is a proof of (ii). From the proof of Lemma 2.1 we know that $z(q, r)$ is continuous and monotonically decreasing in q. As $z(0.5, r) < 0$ if bidders exhibit DARA, it therefore follows that q needs to decrease in order to achieve equilibrium. As a result, $q^* < 0.5$ if bidders exhibit DARA. (iii) of Proposition 2.1 is proven analogously. □

Proposition 2.1 implies that if bidders exhibit CARA, they will enter the FPA and SPA with equal probability. However, bidders will be more likely to enter the SPA if they exhibit DARA, and will be more likely to enter the FPA if they exhibit IARA. These findings follow from the utility equivalence results from Matthews (1983, 1987), who compares auctions for risk averse bidders when the number of bidders in each auction is fixed. Risk averse bidders tend to bid more in the FPA than in the SPA, making the SPA more desirable from the bidders' perspective. At the same time, however, the payment in the SPA is a random variable, making the FPA more desirable. Matthews (1987) finds that a bidder prefers the SPA to the FPA if she exhibits DARA. Conversely, she prefers the FPA if she exhibits IARA. If the bidder exhibits CARA, she is indifferent between the two auctions.[7] Combining these findings with the fact that the expected utility of an auction is decreasing in the number of bidders, gives us Proposition 2.1. For instance, suppose that bidders exhibit DARA. In this case, each bidder is only indifferent between entering a FPA and a SPA when the number of competing bidders is larger in the SPA than in the FPA. Similarly, if bidders exhibit IARA, each bidder is only indifferent between entering a FPA and a SPA when the number of competing bidders is larger in the FPA than in the SPA.

Simulations with utility functions exhibiting different degrees of absolute risk aversion show that q^* remains close to 0.5 for any r. This can be seen in Figures 2.1 to 2.3 in Section 2.4, which show how q^* develops when bidders exhibiting DARA get more risk averse.[8] It seems that even though bidders may highly prefer one auction over the other, there are negative externalities from other bidders entering the auction. This latter effect seems to be rather strong, causing q^* to remain close to 0.5 even when bidders have a strong preference for one of the auctions.

[7] To the best of our knowledge, there is no easy intuitive explanation for Matthews's (1987) finding. Rather, it is based on the mathematical fact that if a bidder's utility is increasing in her value, such that $\frac{\partial u}{\partial v_i} > 0$, and she exhibits DARA (CARA) (IARA), then $\frac{\partial u}{\partial v_i}$ is strictly convex (linear) (strictly concave) in u (for details, see Lemma 1 by Maskin and Riley (1984, p.1479)). By using this fact and by writing the expected utilities in the FPA and SPA as functions of the winning bidders' respective payments, Matthews proves that the certainty equivalent of the random payment in the SPA is smaller than (equal to) (larger than) the payment in the FPA if bidders exhibit DARA (CARA) (IARA).

[8] As decreasing absolute risk aversion is implied by constant relative risk aversion (CRRA), we focus on the effect of different levels of CRRA in our simulations underlying Figures 2.1 to 2.3.

2.4 Auction selection

In this section, we use the insights obtained in Section 2.3 to evaluate the sellers' decisions in Stage 1 of our game. Recall that there are two sellers, who each offer one unit of a homogeneous good in either a FPA or a SPA. With a slight abuse of notation, we will from now on define q as the entry probability into the FPA and $1-q$ as the entry probability into the SPA. The expected revenues are then given by

$$E[R_{FPA}] = \sum_{n_l=0}^{N} \binom{N}{n_l} (q)^{n_l} (1-q)^{N-n_l} R_{FPA}(n_l, r)$$

$$E[R_{SPA}] = \sum_{n_l=0}^{N} \binom{N}{n_l} (1-q)^{n_l} (q)^{N-n_l} R_{SPA}(n_l)$$

where $R_{FPA}(n_l, r)$ is the seller's ex ante expected revenue when the FPA is entered by n_l bidders who have risk parameter r. It represents the expected payment made by the highest of n_l bidders. Similarly, $R_{SPA}(n_l)$ is the seller's ex ante expected revenue when the SPA is entered by n_l bidders. The ex ante expected revenues of both auctions are increasing in the number of bidders n_l (e.g. Kagel and Levin, 1993).

The revenue equivalence theorem states that the ex ante expected revenue from the FPA equals that of the SPA if bidders are risk neutral, that is, $R_{FPA}(n_l, 0) = R_{SPA}(n_l)$ (Vickrey, 1961). Recall that, in equilibrium, bidders enter each auction with equal probability ($q^* = 0.5$) if they are risk neutral (see Lemma 2.2). Hence, it immediately follows that $E[R_{FPA}] = E[R_{SPA}]$ if bidders are risk neutral, and therefore competing sellers will be indifferent between selecting the FPA and the SPA.

If bidders are risk averse, the situation is more complex. Whereas the equilibrium bidding strategy in the SPA is insensitive to changes in risk attitudes, the equilibrium bidding strategy in the FPA is increasing in risk aversion (e.g. Riley and Samuelson, 1981; Maskin and Riley, 1984; Cox et al., 1985, 1988). As a result, the ex ante expected revenue of the FPA is larger than that of the SPA if bidders are risk averse, that is, $R_{FPA}(n_l, r) > R_{SPA}(n_l)$ for $r > 0$. Given our results from Section 2.3, this implies the following for the expected revenues.

Lemma 2.3 *Suppose that seller 1 selects a first-price auction ($a_1 = FPA$) and seller 2 selects a second-price auction ($a_2 = SPA$), and that bidders are risk averse ($r > 0$), exhibit nondecreasing absolute risk aversion and follow the symmetric entry equilibrium defined in Proposition 2.1. The first-price auction then yields more expected revenue than the second-price auction.*

Proof. Proposition 2.1 shows that $q^* \geq 0.5$ if bidders exhibit CARA or IARA, where q^* defines the equilibrium probability of entering the FPA and $1 - q^*$ defines the equilibrium probability of entering the SPA. This permits direct comparison of expected revenues.

$$\begin{aligned} E[R_{FPA}] &= \sum_{n_1=0}^{N} \binom{N}{n_1} (q^*)^{n_1} (1-q^*)^{N-n_1} R_{FPA}(n_1, r) \\ &> \sum_{n_1=0}^{N} \binom{N}{n_1} (q^*)^{n_1} (1-q^*)^{N-n_1} R_{SPA}(n_1) \\ &\geq \sum_{n_2=0}^{N} \binom{N}{n_2} (1-q^*)^{n_2} (q^*)^{N-n_2} R_{SPA}(n_2) = E[R_{SPA}] \end{aligned}$$

The strict inequality is based on the fact that $R_{FPA}(n_1, r) > R_{SPA}(n_1)$ for $r > 0$. To prove that the second inequality holds we rewrite the expected revenues as

$$E[R_{FPA}] = \sum_{n_1=0}^{N} p_{n_1:N}(q^*) R_{FPA}(n_1, r)$$

$$E[R_{SPA}] = \sum_{n_2=0}^{N} p_{n_2:N}(q^*) R_{SPA}(n_2)$$

where $p_{n_1:N}(q^*) = \binom{N}{n_1}(q^*)^{n_1}(1-q^*)^{N-n_1}$ and $p_{n_2:N}(q^*) = \binom{N}{n_2}(1-q^*)^{n_2}(q^*)^{N-n_2}$. We can show that $E[R_{FPA}]$ is continuous and monotonically increasing in q (see Lemma A.2 in Appendix A.1) and that $E[R_{SPA}]$ is continuous and monotonically decreasing in q (see Lemma A.3 in Appendix A.1). As $p_{n_1:N}(q) = p_{n_2:N}(q)$ for $q = 0.5$, it then follows that $p_{n_1:N}(q) > p_{n_2:N}(q)$ for any $q > 0.5$, and $p_{n_1:N}(q) < p_{n_2:N}(q)$ for any $q < 0.5$. Since $q^* \geq 0.5$ if bidders exhibit CARA or IARA (see Proposition 2.1) and since $R_{SPA}(n_2)$ is increasing in n_2, the second inequality must hold. This concludes the proof of Lemma 2.3. □

If competing sellers offer their goods in both FPAs and SPAs, and risk averse bidders endogenously enter one of the auctions, then each bidder is at least as likely to enter the FPA as she is likely to enter the SPA (see Proposition 2.1). This finding, combined with the familiar ranking of ex ante expected revenues for risk averse bidders, gives us Lemma 2.3. Our finding also implies that DARA is a necessary condition for the traditional revenue ranking to reverse. After all, if bidders exhibit DARA, they prefer the SPA over the FPA, which makes them more likely to enter the SPA.

Table 2.1: Payoffs of the auction selection game

Seller 1 \ Seller 2	FPA	SPA
FPA	$\sum_{n_1=0}^{N}\binom{N}{n_1}0.5^{n_1}0.5^{N-n_1}R_{FPA}(n_1,r)$	$\sum_{n_1=0}^{N}\binom{N}{n_1}(q^*)^{n_1}(1-q^*)^{N-n_1}R_{FPA}(n_1,r)$
SPA	$\sum_{n_1=0}^{N}\binom{N}{n_1}(1-q^*)^{n_1}(q^*)^{N-n_1}R_{SPA}(n_1)$	$\sum_{n_1=0}^{N}\binom{N}{n_1}0.5^{n_1}0.5^{N-n_1}R_{SPA}(n_1)$

Only if sufficiently many bidders enter the SPA, the initial advantage of the FPA may be overcome.

We now turn to the auction selection game, where we study which auctions competing sellers select when bidders are risk averse and endogenously enter auctions. Table 2.1 gives the payoffs of the auction selection game of seller 1 (the row player); the payoffs of seller 2 are symmetric. From Lemma 2.2 we know that $q^* = 0.5$ for $a_1 = a_2$. Following from the revenue ranking for risk averse bidders, the strategy combination (FPA, FPA) dominates (SPA, SPA) in terms of total payoffs. The ranking of the other strategy combinations is influenced by the degree of absolute risk aversion of the bidders, as it crucially depends on the value of the equilibrium probability of entry, q^*.

Proposition 2.2 *Suppose that two competing sellers choose between selecting a first-price auction and a second-price auction, and that bidders are risk averse ($r > 0$), exhibit nondecreasing absolute risk aversion and follow the symmetric entry equilibrium defined in Proposition 2.1. Then each seller has a dominant strategy to select the first-price auction.*

Proof. This proof makes use of the mutual best response property of a Nash equilibrium. By Proposition 2.1, $q^* \geq 0.5$ if bidders exhibit CARA or IARA. Further recall that $R_{FPA}(n_l, r) > R_{SPA}(n_l)$, that $E[R_{FPA}]$ is continuous and monotonically increasing in q, and that $E[R_{SPA}]$ is continuous and monotonically decreasing in q (for the latter two findings, see Lemmata A.2 and A.3 in Appendix A.1). To determine the best response for seller $l = \{1, 2\}$, first suppose that seller $\neg l$ selects FPA. Then by the above it follows that

$$0.5^N \sum_{n_l=0}^{N} \binom{N}{n_l} R_{FPA}(n_l, r) > \sum_{n_l=0}^{N} \binom{N}{n_l} (1-q^*)^{n_l} (q^*)^{N-n_l} R_{SPA}(n_l)$$

Similarly, suppose that seller $\neg l$ selects SPA, then

$$\sum_{n_l=0}^{N} \binom{N}{n_l} (q^*)^{n_l} (1-q^*)^{N-n_l} R_{FPA}(n_l, r) > 0.5^N \sum_{n_l=0}^{N} \binom{N}{n_l} R_{SPA}(n_l)$$

This implies that selecting FPA is a dominant strategy for seller $l = \{1, 2\}$ and concludes the proof of Proposition 2.2. □

Proposition 2.2 implies that if bidders exhibit nondecreasing absolute risk aversion, all competing sellers select a FPA. This follows naturally, as in these cases the FPA is ex ante (weakly) preferred to the SPA by both sellers and bidders. If bidders exhibit DARA, however, two opposing effects occur. On the one hand, the FPA generates more ex ante expected revenue than the SPA if bidders are risk averse. On the other hand, if bidders exhibit DARA, they are more likely to enter the SPA than the FPA, that is, $q^* < 0.5$ by Proposition 2.1. Proposition 2.2 implies that DARA is a necessary condition for any equilibrium other than (FPA, FPA) to exist, but it is by itself not sufficient. In the remainder of this section, we demonstrate by example that if bidders exhibit DARA, other equilibria may exist in which sellers select SPAs as well.

2.4.1 An example of auction selection with DARA bidders

Consider the following example, where bidder i has a utility function of the form $u(m_i) = m_i^{(1-\rho)}$, where m_i represents a bidder's payoff and $\rho \in [0,1)$ represents the coefficient of constant relative risk aversion (CRRA).[9] Recall that if bidder i wins the auction, her payoff (m_i) is equal to her private value (v_i) minus her payment (p_i). If bidder i loses the auction, her payoff is equal to zero. Values are distributed according to $F(v) = v^\alpha$ for $v \in [0,1]$, where $\alpha \geq 1$ and takes integer values only. Note that values are uniformly distributed if $\alpha = 1$. An increase in α represents an increase in the skewness of the distribution of values such that higher values are drawn with larger probability. In this case, the ex ante expected revenues are given by

$$R_{FPA}(n_l, r) = \frac{\alpha(n_l - 1)}{\alpha(n_l - 1) + 1 - \rho} \frac{\alpha n_l}{\alpha n_l + 1} \tag{2.2}$$

$$R_{SPA}(n_l) = \frac{\alpha(n_l - 1)}{\alpha(n_l - 1) + 1} \frac{\alpha n_l}{\alpha n_l + 1} \tag{2.3}$$

The bidders' ex ante expected utilities in the auctions are given by

$$E[u|FPA, n_l] = \frac{\alpha}{\alpha n_l + 1 - \rho} \left(\frac{1 - \rho}{\alpha(n_l - 1) + 1 - \rho} \right)^{1-\rho} \tag{2.4}$$

$$E[u|SPA, n_l] = \frac{\alpha}{\alpha n_l + 1 - \rho} \frac{(\alpha(n_l - 1))!}{(\alpha(n_l - 1) + 1 - \rho)!} \tag{2.5}$$

where $(\alpha(n_l - 1) + 1 - \rho)! \equiv \prod_{i=1}^{\alpha(n_l-1)} (i + 1 - \rho)$. The derivations of these

[9] For simplicity, we have chosen to present here the simulations for one of the simplest and most often used utility functions in economics: the power utility function for positive powers. However, qualitatively similar results can be obtained when using a more general utility function, for instance, one exhibiting hyperbolic absolute risk aversion. For a discussion of the characteristics of the power utility function, see Wakker (2008).

results can be found in Appendix A.2.[10]

To analyze which auctions are selected by competing sellers, we use (2.4) and (2.5) to compute the equilibrium probability of entry, q^*, and use (2.2) and (2.3) to compute $\underline{q}$ and $\overline{q}$. Let $\underline{q}$ be defined as the probability of entry for which seller $l = \{1, 2\}$ is indifferent between selecting the FPA and the SPA given that seller $\neg l$ offers a FPA.

$$0.5^N \sum_{n_l=0}^{N} \binom{N}{n_l} R_{FPA}(n_l, r) = \sum_{n_l=0}^{N} \binom{N}{n_l} (1-\underline{q})^{n_l} (\underline{q})^{N-n_l} R_{SPA}(n_l) \quad (2.6)$$

Similarly, let $\overline{q}$ be defined as the probability of entry for which seller $l = \{1, 2\}$ is indifferent between selecting the FPA and the SPA given that seller $\neg l$ offers a SPA.

$$\sum_{n_l=0}^{N} \binom{N}{n_l} (\overline{q})^{n_l} (1-\overline{q})^{N-n_l} R_{FPA}(n_l, r) = 0.5^N \sum_{n_l=0}^{N} \binom{N}{n_l} R_{SPA}(n_l) \quad (2.7)$$

Note that because $R_{FPA}(n_l, r) > R_{SPA}(n_l)$ for $r > 0$, and because $E[R_{FPA}]$ is continuous and monotonically increasing in q (see Lemma A.2 in Appendix A.1), the LHS of (2.7) will be larger than the RHS for any $q \geq 0.5$. Likewise, because $E[R_{SPA}]$ is continuous and monotonically decreasing in q (see Lemma A.3 in Appendix A.1), the LHS of (2.6) will be larger than the RHS for any $q \geq 0.5$. Therefore, both $\underline{q}$ and $\overline{q}$ will be strictly below 0.5.

Figure 2.1 illustrates the values of q^*, $\underline{q}$ and $\overline{q}$ for different values of α and ρ, and for $N = 4$. The numbered regions in Figure 2.1 correspond to different equilibrium outcomes. In region I, where $q > \underline{q}, \overline{q}$, sellers have a dominant strategy to select the FPA. As a result, in this region there is a unique Nash equilibrium and it is given by the strategy combination (FPA, FPA). In region II, where $q < \underline{q}, \overline{q}$, the unique Nash equilibrium is given by (SPA, SPA). In region III (visible for some parameter values in Figure 2.1 but not explicitly indicated), $\underline{q} < q < \overline{q}$. As $E[R_{FPA}]$ is increasing in q and $E[R_{SPA}]$ is decreasing in q, it follows that in this case, the auction selection game is in fact a coordination game. The Nash equilibria are then given by (FPA, FPA), (SPA, SPA) and one involving mixed strategies.[11]

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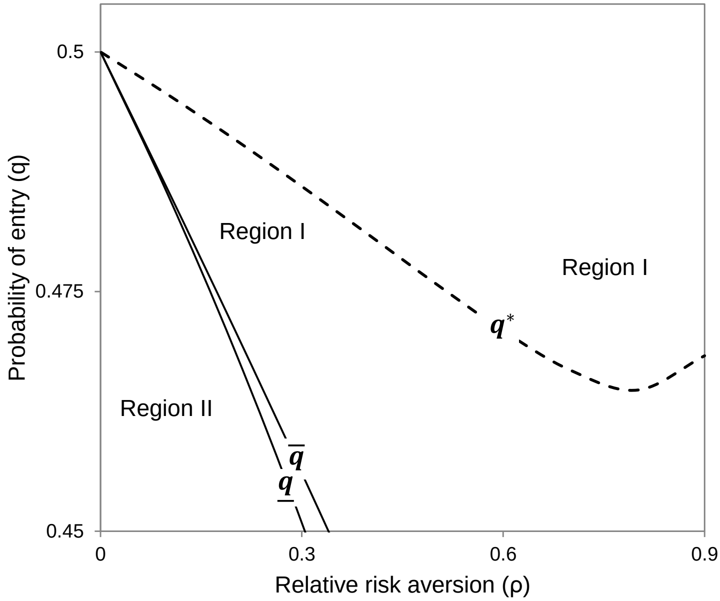
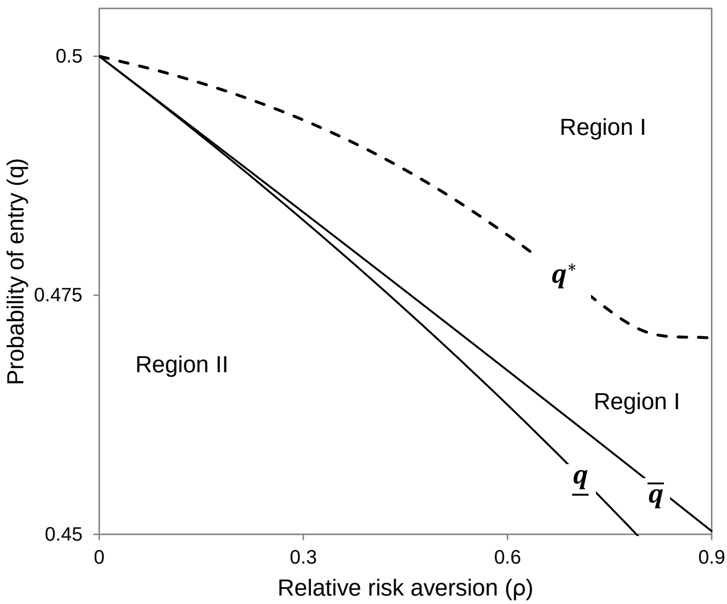
[10] An alternative way of formulating $E[u|SPA, n_l]$ is as a function of the gamma function, Γ. In this case, it is given by

$$E[u|SPA, n_l] = \frac{\alpha}{\alpha n_l + 1 - \rho} \frac{\Gamma(\alpha(n_l - 1) + 1)\Gamma(2 - \rho)}{\Gamma(\alpha(n_l - 1) + 2 - \rho)}$$

[11] Note that there may exist a fourth possible equilibrium outcome, i.e., where $\underline{q} > q > \overline{q}$. In this case, the auction selection game is in fact an anti-coordination game, such that

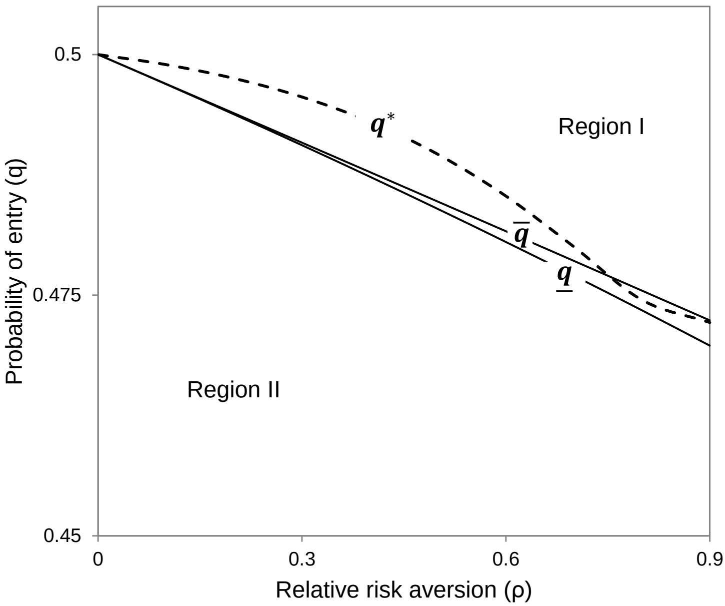


(a) $\alpha = 1$

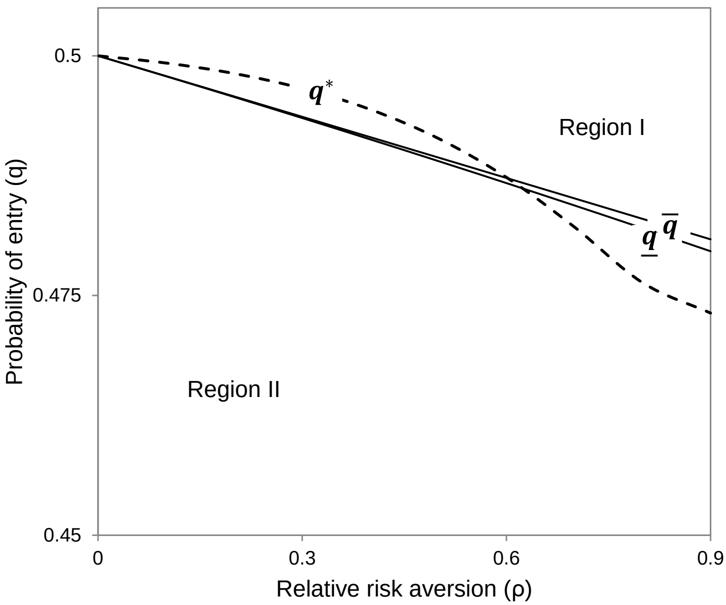


(b) $\alpha = 5$

Figure 2.1: Effect of the distribution of values on auction selection with CRRA bidders (where $F(v) = v^{\alpha}$ and $N = 4$)



(c) $\alpha = 10$



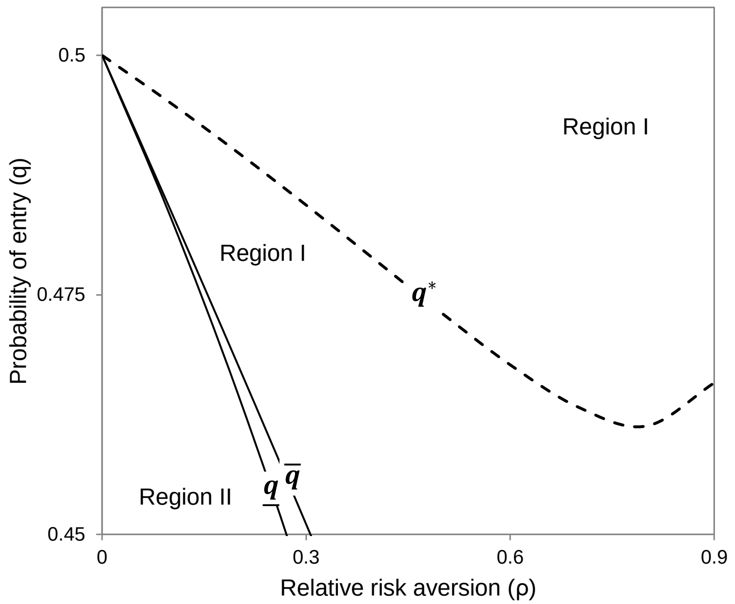
(d) $\alpha = 15$

Figure 2.1: Effect of the distribution of values on auction selection with CRRA bidders (where $F(v) = v^{\alpha}$ and $N = 4$)

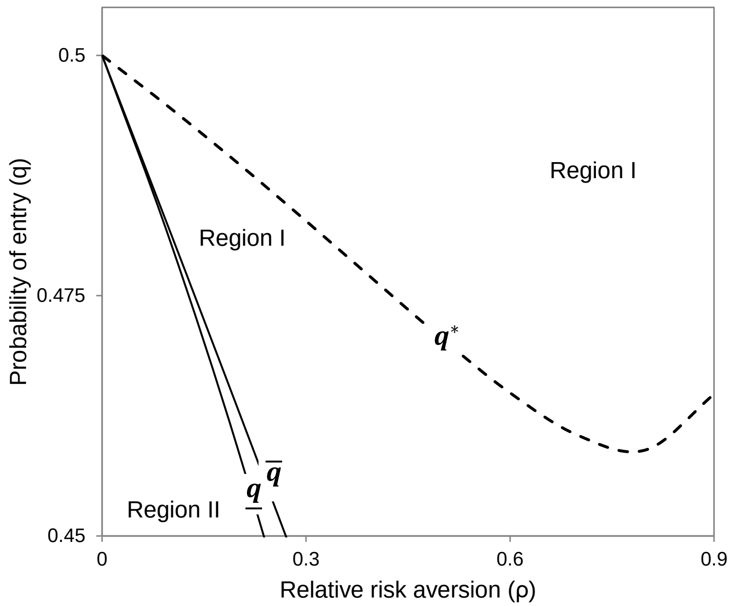
Figure 2.1a shows that, when values are uniformly distributed, q^* remains above $\underline{q}$ and $\overline{q}$ for any $\rho \in (0, 1)$. This implies that sellers have a dominant strategy to select the FPA. However, as the distribution function becomes more skewed (α becomes larger), $\underline{q}$ and $\overline{q}$ shift upwards, leading to an increase in region II at the expense of region I. As a result, we find that if the distribution of values is sufficiently skewed and bidders are sufficiently risk averse then q^* also moves through regions II and III (see Figures 2.1c and 2.1d), such that in equilibrium both sellers could also end up selecting SPAs. Our finding is analogous to that of Smith and Levin (1996), who show, in a model where bidders can choose whether or not to enter an auction at an entry cost, that the traditional revenue ranking for risk averse bidders can be reversed if the distribution of values is sufficiently skewed. The reason for these results is that an increase in α reduces the variance in payments generated in the SPA and thereby decreases the difference in ex ante expected revenues between the FPA and SPA. This can immediately be seen from (2.2) and (2.3), where an increase in α leads to a relatively larger change in the ex ante expected revenue for the SPA than for the FPA.

Smith and Levin (1996) suspect that increasing the number of bidders (N) affects the revenue ranking between the FPA and SPA in a similar way as increasing the skewness of the distribution does (α). They therefore "conjecture that SPA would tend to be favored by the seller more often in markets with many potential bidders than in markets with few" (Smith and Levin, 1996, p.558). We find that this does not hold for our setting. Rather, we find that increasing the number of bidders decreases both $\underline{q}$ and $\overline{q}$, thereby making it less likely that the dominance of FPA is overthrown. Figures 2.2 and 2.3 show the effect of increasing N to 6 and 9 when values are uniformly distributed ($\alpha = 1$) and when the distribution of values is rather skewed ($\alpha = 15$), respectively. This finding extends to larger N as well.

the resulting Nash equilibria are given by (FPA, SPA), (SPA, FPA) and an equilibrium involving mixed strategies. While we do not find any evidence for cases where $\underline{q} > \overline{q}$ in our simulations, we cannot rule out that such cases exist for certain distribution functions or utility functions.

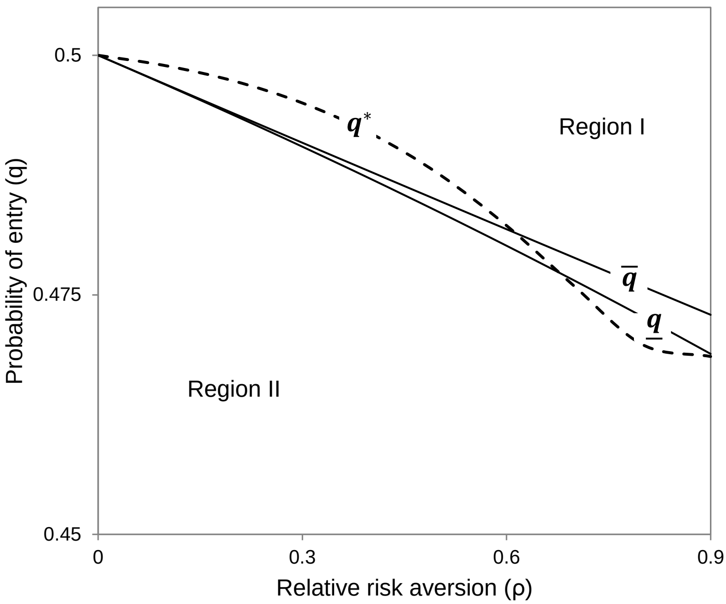


(a) $N = 6$

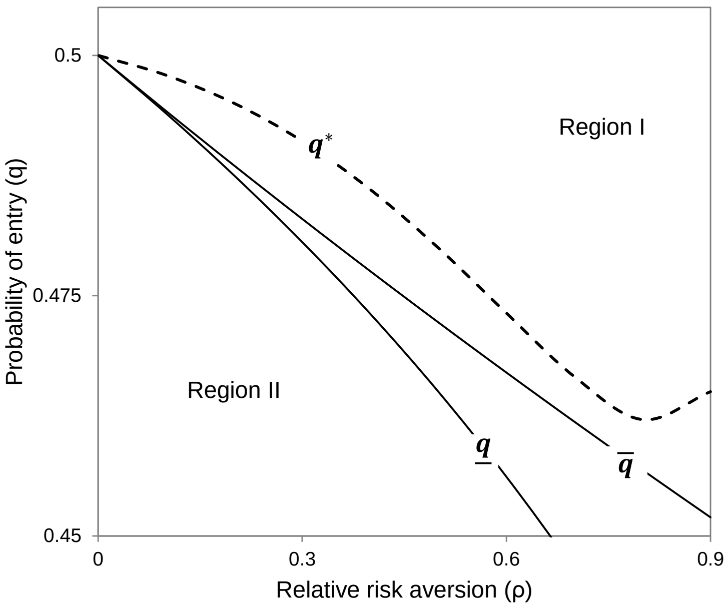


(b) $N = 9$

Figure 2.2: Effect of N on auction selection with CRRA bidders and a uniform distribution of values (where $F(v) = v^\alpha$ and $\alpha = 1$)



(a) $N = 6$



(b) $N = 9$

Figure 2.3: Effect of N on auction selection with CRRA bidders and a skewed distribution of values (where $F(v) = v^{\alpha}$ and $\alpha = 15$)

2.5 Extensions

In this section, we consider extensions where bidders have heterogeneous risk attitudes (Section 2.5.1), where both goods are owned by the same seller (Section 2.5.2) and where the number of sellers is increased to $M > 2$ (Section 2.5.3).

2.5.1 Heterogeneous risk attitudes

Our model assumes that bidders are ex ante homogeneous, meaning that they all maximize the same utility function and do not know their own value for the good before deciding which auction to enter. In this sense, bidders' entry decisions are modeled as a game of complete information. In Section 2.3, we show that this results in a mixed strategy Nash equilibrium, where each bidder enters one auction with probability q^* and enters the other auction with probability $1 - q^*$. By the purification theorem of Harsanyi (1973), our mixed strategy Nash equilibrium can be interpreted as a pure strategy Bayesian Nash equilibrium of an entry game with incomplete information, for instance, one where bidders have heterogeneous risk attitudes.

Like before, let us assume that q^* denotes the equilibrium probability of entry into the FPA and $1 - q^*$ denotes the equilibrium probability of entry into the SPA. Recall that if bidders are homogenously risk neutral ($r = 0$), the equilibrium probability of entry equals $q^* = 0.5$ (see Lemma 2.2). If bidders are homogeneously risk averse ($r > 0$), then $q^* = 0.5$ if bidders exhibit CARA, $q^* < 0.5$ if bidders exhibit DARA and $q^* > 0.5$ if bidders exhibit IARA (see Proposition 2.1). This suggests that for homogeneous bidders a range of risk parameters around risk neutrality exists, such that the equilibrium probability of entry q^* is constant in r if bidders exhibit CARA, is decreasing in r if bidders exhibit DARA, and is increasing in r if bidders exhibit IARA. Let us denote this range of risk aversion parameters by $r \in [0, r^*)$. From Figures 2.1 to 2.3, it can be seen that if homogeneous bidders exhibit DARA, q^* is indeed initially decreasing in the risk parameter (ρ), but becomes increasing as bidders get very risk averse ($\rho > 0.8$).

Now suppose that bidders are heterogeneous, i.e., they all maximize the same utility function exhibiting either decreasing, constant, or increasing absolute risk aversion, but have different risk parameters $r_i \in [0, r^*)$, which are independently drawn from a distribution function $G(r)$. Before entry, each bidder knows her own risk parameter (r_i) and the distribution of other risk parameters ($G(r)$). We may then follow the approach of Pevnitskaya (2004) and find that there exists a self-selection effect when heterogeneous bidders decide between entering the FPA and SPA. More specifically, as

q^* is decreasing in r for homogeneous bidders exhibiting DARA, it can be shown that for heterogeneous bidders exhibiting DARA there exists a cut-off point r' such that the more risk tolerant bidders ($r < r'$) enter the FPA and the more risk averse bidders ($r > r'$) enter the SPA. For heterogeneous bidders exhibiting IARA the self-selection effect is reversed: more risk tolerant bidders enter the SPA and more risk averse bidders enter the FPA. For the case of heterogeneous bidders exhibiting CARA anything goes.

In an experimental study, where bidders choose between entering an English auction and a FPA, Ivanova-Stenzel and Salmon (2008a) find no support for a selection effect based on risk aversion. To analyze the self-selection effect, the authors use the amount of overbidding as a measure of risk aversion. More specifically, they assume that bidders preferences can be described by $u(m_i) = m_i^{1-\rho}$, which results in an equilibrium bidding strategy $b(v) = ((n_l - 1)/(n_l - \rho))v$ when values are uniformly distributed between $[0, 1]$. They find that neither risk aversion nor, more generally, the degree of overbidding has a statistically significant effect on bidders' entry decisions. At first sight, this does not seem to be in line with our findings. It would therefore be interesting to further explore what drives the differences in results between theory and experiment. Also interesting, but beyond the scope of the present study, would be to investigate what bidder heterogeneity implies for the sellers' decisions in the auction selection stage.

2.5.2 Monopoly

Recently, some sellers have started offering a single good in multiple selling mechanisms at the same time. A Dutch travel agency,[12] for instance, sells holidays through ascending auctions, next to selling them at a posted price. In the United Kingdom, one company[13] offers its customers two auction formats from which they may choose: FPAs and lowest unique bid auctions. This suggests that the mechanism through which goods are sold has become the subject of versioning. Therefore, we extend our model to a monopoly setting. Consider a monopolist who sells two units of a homogeneous good and decides to offer these in two simultaneous auctions. He can either choose to offer two FPAs, two SPAs, or a combination of a FPA and a SPA. The monopolist's objective is to maximize the sum of expected revenues of each strategy profile listed in Table 2.1. Alternatively, the monopoly setting can be interpreted as representing the auction selection decisions of competing sellers when they collude.

[12] Emesa.nl

[13] Auctionair.co.uk

Proposition 2.3 *Suppose that a monopolist sells his goods in two simultaneous auctions and chooses between first-price and second-price auctions, and that bidders are risk averse ($r > 0$) and follow the symmetric entry equilibrium defined in Proposition 2.1. Then there exists a range of risk parameters around risk neutrality such that a monopolist prefers to offer both units in first-price auctions.*

Proof. Recall that $q^* = 0.5$ if $a_1 = a_2$ (see Lemma 2.2). Additionally, recall that the traditional revenue ranking implies that $R_{FPA}(n_l, r) > R_{SPA}(n_l)$ for $r > 0$. It therefore follows immediately that the sum of expected revenues of (FPA, FPA) is greater than that of (SPA, SPA). Consequently, to prove Proposition 2.3, it suffices to show that the sum of expected revenues of (FPA, FPA) is greater than that of (FPA, SPA). The sum of expected revenues of offering both a FPA and a SPA is given by

$$\sum_{n_l=0}^{N} \binom{N}{n_l} (q^*)^{n_l} (1-q^*)^{N-n_l} R_{FPA}(n_l, r) \\ + \sum_{n_l=0}^{N} \binom{N}{n_l} (1-q^*)^{n_l} (q^*)^{N-n_l} R_{SPA}(n_l)$$

The sum of expected revenues of two FPAs is given by

$$0.5^N \sum_{n_l=0}^{N} \binom{N}{n_l} R_{FPA}(n_l, r) + 0.5^N \sum_{n_l=0}^{N} \binom{N}{n_l} R_{FPA}(n_l, r)$$

To prove by contradiction, assume that the sum of expected revenues of (FPA, SPA) is at least as large as that of (FPA, FPA).

$$\sum_{n_l=0}^{N} \binom{N}{n_l} \Big\{ [(q^*)^{n_l} (1-q^*)^{N-n_l} - 2 * 0.5^N] R_{FPA}(n_l, r) \\ + (1-q^*)^{n_l} (q^*)^{N-n_l} R_{SPA}(n_l) \Big\} \geq 0 \tag{2.8}$$

By the revenue equivalence theorem, $R_{FPA}(n_l, 0) = R_{SPA}(n_l)$, and by Lemma 2.2, $q^* = 0.5$ for $r = 0$. At risk neutrality ($r = 0$), the sum of expected revenues of (FPA, FPA) must be equal to that of (FPA, SPA). Consequently, it suffices to show that at $r = 0$ the derivative of (2.8) with respect to r is nonnegative. Differentiating (2.8) with respect to r produces the following equation.

$$\sum_{n_l=0}^{N} \binom{N}{n_l} \Bigg\{ [(q^*)^{n_l}(1-q^*)^{N-n_l} - 2*0.5^N] \frac{\partial R_{FPA}(n_1, r)}{\partial r} \\ + (q^*)^{n_l-1}(1-q^*)^{N-n_l-1}[n_l - q^*N] \frac{dq^*}{dr} R_{FPA}(n_l, r) \\ + (1-q^*)^{n_l-1}(q^*)^{N-n_l-1}[(1-q^*)N - n_l] \frac{dq^*}{dr} R_{SPA}(n_l) \Bigg\} \geq 0$$

We now evaluate this at $r = 0$, which by Lemma 2.2 implies $q^* = 0.5$.

$$\sum_{n_l=0}^{N} \binom{N}{n_l} \Bigg\{ -0.5^N \frac{\partial R_{FPA}(n_1, r)}{\partial r} + 0.5^{N-2}[n_l - 0.5N] \frac{dq^*}{dr} R_{FPA}(n_l, 0) \\ + 0.5^{N-2}[0.5N - n_l] \frac{dq^*}{dr} R_{SPA}(n_l) \Bigg\} \geq 0$$

where the last two terms cancel out as $R_{FPA}(n_l, 0) = R_{SPA}(n_l)$ and where $\frac{\partial R_{FPA}(n_l,0)}{\partial r} > 0$. As a result, the equation above is strictly negative, contradicting our assumption. This concludes the proof of Proposition 2.3. □

Proposition 2.3 states that, for some range around risk neutrality, a monopolist prefers to offer two FPAs to offering them in different auctions or in SPAs. This result is independent of whether bidders exhibit CARA, DARA or IARA. In case of CARA, however, we show that the result is more general.

Corollary 2.1 *Suppose that that a monopolist sells his goods in two simultaneous auctions and chooses between first-price and second-price auctions, and that bidders are risk averse ($r > 0$), exhibit constant absolute risk aversion, and follow the symmetric entry equilibrium defined in Proposition 2.1. Then a monopolist prefers to offer both units in first-price auctions to offering them in a first-price and second-price auction, which is preferred to offering them in second-price auctions.*

Proof. By Proposition 2.1, we know that with CARA bidders $q^* = 0.5$ for every r. As $R_{FPA}(n_l, r) > R_{SPA}(n_l)$ for $r > 0$, it follows immediately that the sum of expected revenues from (FPA, FPA) is greater than that of (FPA, SPA), which is in turn greater than that of (SPA, SPA). □

Simulations for utility functions exhibiting different degrees of absolute risk aversion consistently show that a monopolist prefers to select only FPAs. We therefore conjecture that Corollary 2.1 holds as well for bidders exhibiting DARA or IARA. Our findings are consistent with traditional revenue ranking theorems, but seem less consistent with practice in online auctions. Whereas our results indicate that it is not profitable to use auction design as a means of versioning, this is exactly what happens on the Internet. Perhaps such versioning by monopolists can only be explained when bidders have heterogeneous or non-standard preferences. Future research might therefore consider heterogeneous risk averse (and risk seeking) bidders or take into account behavioral assumptions such as reference-dependent preferences and competitiveness. Taking into account more sophisticated assumptions might better explain bidders' entry decisions and, hence, the form that auction versioning by monopolists takes.

2.5.3 $M > 2$ sellers

Our results can easily be extended to a market with $M \geq 2$ competing sellers. From Lemma 2.2, it immediately follows that if all sellers offer the same auction or if bidders are risk neutral ($r = 0$), each bidder enters each auction $a_l = 1, 2, ..., M$ with probability $q_l^* = (1/M)$. Now suppose that seller l offers a FPA and all other $M - 1$ sellers offer SPAs, and that bidders are risk averse ($r > 0$). Then by Proposition 2.1, the equilibrium probability of entry equals $q_l^* = q_{\neg l}^* = (1/M)$ if bidders exhibit CARA. Likewise, if bidders exhibit DARA, $q_l^* < (1/M)$ and $q_{\neg l}^* > (1/M)$, and if bidders exhibit IARA, $q_l^* > (1/M)$ and $q_{\neg l}^* < (1/M)$. In the auction selection game, sellers will continue to have a dominant strategy to select FPAs if bidders exhibit CARA or IARA.

2.6 Conclusion

The main objective of this chapter is to investigate which auctions are selected by competing sellers when they may choose between first-price and second-price auctions and when risk averse bidders endogenously enter one of the auctions. We construct a three-stage game in which two units of a homogenous good are offered simultaneously to a group of N homogeneously risk averse bidders. At Stage 1, the sellers each select an auction; at Stage 2, each bidder learns which auctions have been selected and decides to enter one of the auctions; finally, at Stage 3, the auctions are conducted.

Our key findings can be summarized along two lines. First, we show that when bidders may choose between entering the first-price and second-price auction, then a symmetric equilibrium exists involving mixed strategies, where the mixing probabilities depend on the bidders' degree of absolute risk aversion. If bidders exhibit risk neutrality or constant absolute risk aversion, they will enter each auction with equal probability. If bidders exhibit decreasing absolute risk aversion, however, they will enter the second-price auction with greater likelihood, and if bidders exhibit increasing absolute risk aversion, they will enter the first-price auction with greater likelihood. Second, we find that if bidders exhibit nondecreasing absolute risk aversion, competing sellers have a dominant strategy to select first-price auctions. We demonstrate by example that if bidders exhibit decreasing absolute risk aversion, sellers may also select second-price auctions if the distribution of private values is sufficiently skewed.

Whereas traditional revenue ranking theorems predict that competing sellers should prefer the first-price auction when bidders are risk averse, in reality most sellers seem to offer English auctions, which are strategically equivalent to second-price auctions. Our analysis suggests that this could be explained by the presence of decreasing absolute risk aversion. Additionally, even though experimental studies often assume that values are uniformly distributed, it is possible that in many real-world auctions values actually follow a more skewed distribution. Future research might further explore this, both experimentally and empirically.

In the context of online auctions, it would also be interesting to explore to which extent our findings depend on the assumption that bidders know how many other bidders actually enter each auction. After all, on the Internet, bidders may not be aware of how many competing bidders participate in an auction. Matthews (1987) shows that the preference rankings for risk averse bidders can be extended to a setting where the number of bidders participating in each auction is concealed. We therefore conjecture that in such a setting, there exists an entry equilibrium analogous to the one we find in this paper. Future research may consider the effects of concealing the number of competing bidders on bidders' entry decisions and its implications for the auction selection decisions of competing sellers.

Chapter 3

Understanding preferences for ascending auctions, Buy-It-Now auctions and posted prices*

3.1 Introduction

The rise in popularity of Internet retailing has led to increased diversity in selling mechanisms. Besides buying goods at a posted price, consumers may also participate in a myriad of online auctions. In recent years, online auctioneers have experimented with design features that could not be implemented in offline auctions. This ultimately led to the development of new auction formats. For instance, online auctioneers have introduced posted price features in their auctions through the use of Buy-It-Now options. In auctions with such an option, consumers can bid for a good but can additionally choose to end the auction by buying the good at a posted price. Both eBay and Yahoo—two of the most successful online marketplaces—currently offer three types of selling mechanisms: ascending auctions, Buy-It-Now auctions and posted prices. This diversity in selling mechanisms allows consumers to choose not only from which seller but even in which type of selling mechanism to buy. Understanding how consumers decide which selling mechanism to enter is of interest to any seller who is striving to increase revenue. After all, in a market in which goods are sold in competing mechanisms, attracting consumers is of utmost importance as

*The study presented in this chapter is joint work with Kris De Jaegher and Stephanie Rosenkranz. An earlier version of this study is published as a discussion paper (see Delnoij et al., 2014) this both increases the likelihood to sell at a posted price and drives up the price in auctions (e.g. Kagel and Levin, 1993). In this chapter, we therefore examine which selling mechanism—ascending auction, Buy-It-Now auction or posted price—is preferred by consumers, and additionally analyze what drives these preferences.

Consider a consumer who wants to buy a single unit of a good and can either do this at a posted price or by participating in an ascending or Buy-It-Now auction. How does she decide which mechanism to enter? We consider two explanations: First, consumers may decide to enter a selling mechanism based on the expected monetary payoffs this mechanism provides. When deciding whether or not to buy at a posted price, for instance, a consumer may consider the price in relation to her value for the good. In selling mechanisms involving multiple consumers competing for the same good, a consumer's entry decision will not only be driven by the price but also by her chances of winning. In standard auctions,[1] the expected monetary payoffs of bidding can be predicted when consumers bid according to the symmetric Bayesian Nash equilibrium bidding strategy (see Krishna, 2010; Menezes and Monteiro, 2005). However, payoffs may be difficult to predict when dealing with non-standard auctions or when bidding strategies involve jump bidding and last-minute bidding.

Second, consumers' entry decisions may be affected by aspects of the selling mechanisms other than expected monetary payoffs. Consumers are heterogeneous in their attitudes and psychological traits, which may result in heterogeneous preferences over, for instance, buying versus bidding. The literature has identified several consumer characteristics that may explain preferences for buying or bidding, either in different selling mechanisms or within a Buy-It-Now auction. Budish and Takeyama (2001), Mathews and Katzman (2006) and Reynolds and Wooders (2009) find that risk averse consumers are more likely to select the Buy-It-Now option than risk tolerant consumers. This is in line with Pevnitskaya (2004) and Palfrey and Pevnitskaya (2008), who demonstrate that if consumers decide whether or not to enter a first-price auction, only more risk tolerant consumers enter. Mathews (2004) and Gallien and Gupta (2007) show that consumers who are highly impatient prefer to buy immediately, rather than to wait for the outcome of an auction. Furthermore, loss aversion may influence the decision between buying and bidding if the Buy-It-Now price serves as a reference price (e.g. Shunda, 2009; Popkowski Leszczyc et al., 2009). Finally, whereas bidding in an English auction is supposedly regret-free (Engelbrecht-Wiggans and Katok, 2007), participating in a Buy-It-Now

[1] A standard auction is defined as an auction in which the bidder with the highest bid wins.

auction presents several opportunities for regret: A consumer may regret bidding when she loses the good due to a competitor selecting the Buy-It-Now option or when she wins at a price higher than the Buy-It-Now price. Conversely, she may regret buying when she could have gotten a lower price in the auction. Tan et al. (2005) show that anticipating regret indeed influences the decision to buy or bid in Buy-It-Now auctions.

The present study provides experimental evidence on consumers' preferences over three selling mechanisms: ascending auction, Buy-It-Now auction and posted price. Which selling mechanism is preferred? Can these preferences be explained by differences in expected payoffs across mechanisms (monetary incentives), or do consumer characteristics (non-monetary incentives) also play a role? To answer these questions, our exploratory experiment involves subjects making a series of entry decisions between three pairs of selling mechanisms. That is, subjects choose between posted price and ascending auction, between posted price and Buy-It-Now auction, and between Buy-It-Now auction and ascending auction.

To maximize external validity, the selling mechanisms in the experiment are modeled after those found in online marketplaces. In each mechanism, a single unit of a fictitious good is sold. Subjects can win this good either by bidding for it or by buying it at a posted price. In the ascending and Buy-It-Now auction, subjects may place bids manually. The subject with the highest bid after a fixed deadline wins the good. In the posted price and Buy-It-Now auction, subjects may buy the good immediately by selecting a permanently available Buy-It-Now option. The first subject to select this option wins the good with certainty.[2] Since previous research has shown that a consumer's value may impact her decision to enter an auction (e.g. Menezes and Monteiro, 2000; Ivanova-Stenzel and Salmon, 2011; Aycinena et al., 2015), subjects are informed about their values and the Buy-It-Now price before making their entry decisions. The role of monetary incentives in entry decisions is measured by the expected payoffs of buying versus bidding. We further include a number of psychometric measures in the experiment, which together constitute the non-monetary incentives. These measures involve a risk attitude elicitation task, a loss attitude elicitation task, and a questionnaire measuring impatience, sensation seeking and regret.

Our results show that entry decisions between selling mechanisms are indeed impacted by expected payoffs. That is, we find that, for a given posted or Buy-It-Now price, subjects are more likely to enter a mecha-

[2]Note that all of the selling mechanisms in the experiment involve risk. Whereas entering a mechanism which involves bidding is risky due to the nature of the bidding process, entering a mechanism which involves buying is risky due to the first-come, first-served rule implemented in the experiment.

nism which involves bidding when values are below some cut-off, and more likely to enter a mechanism which involves buying when values are above this cut-off. However, we find that non-monetary incentives play a role as well. Impatience makes subjects less likely to enter ascending auctions and risk aversion makes subjects more likely to enter mechanisms which involve bidding. We additionally find strong evidence for the existence of a gender difference in entry decisions. Whereas males are more likely to enter a mechanism which involves bidding, females are more likely to enter a mechanism which involves buying.

This study contributes to the literature on consumers' preferences over and endogenous entry into auctions.[3] This literature has examined which auction formats are preferred by consumers in general and by certain types of consumers in particular. It additionally analyzed how consumers choose whether or not to enter an auction with an outside option, and choose between entering several auction formats. In a series of experiments, Ivanova-Stenzel and Salmon (2004a,b, 2008a,b, 2011) compare entry into the English auction to entry into the first-price auction. Like Engelbrecht-Wiggans and Katok (2005), they find that the English auction is preferred to the first-price auction. Loss aversion and aversion to the dynamic bidding process cannot explain this finding; the evidence on risk aversion is mixed. Ivanova-Stenzel and Salmon (2011) further find that if consumers have information about their values prior to deciding which auction to enter, those consumers with lower values enter first-price auctions more often and those with higher values enter English auctions more often. Other experimental studies on endogenous entry are those by Palfrey and Pevnitskaya (2008), Ertaç et al. (2011) and Aycinena et al. (2015), who examine the effects of risk aversion, joy of winning and competitiveness, respectively. To the best of our knowledge, the experimental literature has only considered standard auctions up to this point. Our study is therefore the first to consider entry into non-standard auctions and additionally controls for a wide range of consumer characteristics.

Our study also adds to the literature on Buy-It-Now auctions.[4] Most studies in this strand of literature attempt to explain the mechanism's success by examining the assumptions under which a Buy-It-Now auction generates more revenue to sellers than alternative selling mechanisms, e.g., risk aversion (e.g. Budish and Takeyama, 2001; Mathews and Katzman,

[3]For example, see Matthews (1983, 1987), McAfee and McMillan (1987b), Levin and Smith (1994), Smith and Levin (1996) and Fibich et al. (2006). Extensive overviews of the literature on entry into auctions can be found in Kagel and Levin (2014) and Aycinena et al. (2015).

[4]For a recent and extensive overview of the literature on Buy-It-Now auctions, see Tsuchihashi (2016).

2006; Reynolds and Wooders, 2009), impatience (e.g. Mathews, 2004; Gallien and Gupta, 2007), reference-dependent preferences (e.g. Shunda, 2009; Popkowski Leszczyc et al., 2009), anticipated emotions such as regret and satisfaction (Tan et al., 2005), and personality traits such as competitiveness, hedonic need fulfilment and impulse-buying tendencies (Angst et al., 2008). A line of research that is closely related to ours examines the impact of auction participation costs on entry, bidding, and buying decisions in Buy-It-Now auctions (e.g. Wang et al., 2008; Sun et al., 2010; Che, 2011). These studies show that when consumers make endogenous entry decisions, adding a Buy-It-Now option to an auction may increase the seller's expected revenue. Our study is complementary to these studies, as we identify additional factors that drive entry decisions into ascending auctions, Buy-It-Now auctions and posted prices.

Furthermore, this study contributes to the literature examining gender differences in competitive preferences. Various experimental studies have shown that females are less willing to enter competitive environments than males (e.g. Gneezy et al., 2003; Gneezy and Rustichini, 2004; Niederle and Vesterlund, 2007), and, in the context of auctions, are less willing to enter first-price auctions (Aycinena et al., 2015). Our study provides further evidence for the finding that females shy away from competition and that males embrace it.

The remainder of this chapter is structured as follows. Section 3.2 describes the design and procedures of our experiment. Section 3.3 contains a description of our sample and Section 3.4 provides the results of the analysis of our data. Section 3.5 discusses our findings and provides concluding remarks.

3.2 Experimental design and procedures

Our experimental design aims at studying entry decisions between three selling mechanisms. It follows to some extent the methods used by Ivanova-Stenzel and Salmon (2004a,b, 2008a,b, 2011), but is modified in several ways. Section 3.2.1 explains how the three selling mechanisms are implemented in the experiment, Section 3.2.2 describes the psychometric measures and Section 3.2.3 describes the procedures of the experiment. For the instructions and descriptions of additional tasks and questionnaires, see Appendices B.1 and B.2, respectively.

3.2.1 Selling mechanisms

The experiment involves subjects playing three types of selling mechanisms: ascending auctions, Buy-It-Now (BIN) auctions and posted prices. In each selling mechanism, a single unit of a fictitious good is sold. The value of this good is drawn independently for each subject from a uniform distribution with support [0,100], where values are denoted in experimental currency units (ECU). If a subject wins the good, she receives a payoff equal to her value minus her payment. If a subject does not win the good, she receives a payoff of zero. Mechanisms are run in continuous time, meaning that subjects have 45 seconds to take an action and possibly win the good.[5] Each mechanism has different rules defining the actions subjects can take, and determining the winner and payment. Whereas subjects can only bid in the ascending auction and can only buy in the posted price, they can take both actions in the BIN auction.

In the ascending auction, subjects can place multiple bids and bids can be observed by all subjects participating in the auction. The bidding process in our experiment therefore differs from that of previous research (e.g. Ivanova-Stenzel and Salmon, 2004a,b, 2008a,b, 2011). Whereas in most previous work the ascending auction is in fact a Japanese or ascending clock auction,[6] thereby resembling an English auction, we allow subjects to place bids themselves, where bids are restricted to integer values between 0 and 150. As a consequence, bidding strategies may involve jump bidding and last-minute bidding. The subject with the highest bid after 45 seconds wins the auction and pays a price equal to the winning bid.

In the BIN auction, subjects can bid for the good according to the rules of the ascending auction but can additionally buy it immediately at a posted, fixed price by selecting the BIN option. This price (henceforth BIN price) is randomly drawn from a uniform distribution with support [0,100]. The BIN option is permanently available and subjects can choose to end

[5] Alternatively, the mechanisms could be run in discrete time, organized in one period for posted price and in multiple periods for the ascending and BIN auction (see Ariely et al., 2005). In such a design, subjects in the posted price simultaneously indicate whether or not they want to buy the good. If only one subject has chosen to buy, this subject wins the good with certainty; if multiple subjects have chosen to buy, the good is allocated randomly. In the ascending auction, subjects simultaneously place a single bid in each period. After each period, the current highest bid is revealed and subjects are again allowed to place a bid. The auction ends after a certain amount of periods and the subject with the highest bid wins. In the BIN auction subjects may place bids according to the rules of the ascending auction, but may additionally choose to end the auction in each period by buying the good at a posted price. This approach has two drawbacks: First, the posted price and BIN auction are turned into lotteries. Second, whereas the posted price is a simultaneous move game, the auctions have elements of a sequential game. As a result, the BIN auction is no longer a perfect combination of the posted price and ascending auction.

[6] In Japanese or ascending clock auctions the price starts at zero and increases gradually until a maximum of 150. This process continues until one of the bidders indicates that she is withdrawing from the auction, with the remaining bidder winning the auction at the price at which the other bidder dropped out.

the auction at any time.[7] The first subject to select the BIN option wins and pays the BIN price.[8] If the BIN option is never selected, the rules of the ascending auction dictate the winner, i.e., the subject with the highest bid wins and pays the winning bid.

In the posted price, subjects cannot bid for the good but can only buy by selecting the BIN option. The rules determining the winner and payment are the same as in the BIN auction, i.e., the first subject to select the BIN option wins and pays the BIN price. In case none of the subjects select the BIN option within 45 seconds, all receive a payoff of zero. It is worth pointing out that the posted price does not function as an outside option, where all subjects choosing this option receive a positive payoff as, for example, in Palfrey and Pevnitskaya (2008). Instead, because of the implementation of a first-come, first-served rule, only one of the subjects in the posted price may receive a positive payoff.

Throughout the experiment subjects face only one competitor in each mechanism, i.e., $N = 2$. Not only does this maximize the number of observations while keeping the number of subjects limited, it also eliminates entry coordination.[9] This means that subjects have no incentive to enter a mechanism with the sole purpose of trying to be the only one choosing this mechanism and, hence, win with certainty.[10]

3.2.2 Psychometric measures

We elicit five consumer characteristics during the experiment. The measures involve a risk attitude elicitation task, a loss attitude elicitation task, and a questionnaire measuring impatience, sensation seeking and regret.

[7] An alternative would be to use a temporary BIN option, like Peeters et al. (2016), where subjects are asked at the start of the trading period whether they want to buy the commodity at the posted price. Although all subjects make this decision, only the decision of a randomly chosen subject is implemented. The bidding process only commences if this subject did not select the BIN option.

[8] In case both subjects select the BIN option simultaneously, the winner of the good is randomly determined. However, because mechanisms are run in continuous time and the BIN option is permanently available in both the posted price and the BIN auction, the probability that this happens is very small. In fact, this never happened during our experiment.

[9] Even though we keep the number of competitors in each mechanism fixed, our experiment still involves a coordination problem. That is, subjects may not only consider their own expected payoffs and preferences in their entry decisions, but may also consider the expected payoffs and preferences of their competitors, as this could influence bidding strategies and, hence, prices.

[10] An alternative design would have been to offer two goods in two simultaneously running mechanisms, like Ivanova-Stenzel and Salmon (2008a, 2011) do. In this case, subjects need not only take into account expected payoffs and their preferences, but also need to consider the number of subjects that will enter the same mechanism.

A complete description of these tasks and questionnaires can be found in Appendix B.2 in Tables B.1 to B.5.

Attitudes towards risk are measured using the method introduced by Holt and Laury (2002), which consists of a sequence of ten paired lottery choices each time involving a safe payment and a risky payment. Both lotteries have a high and a low payoff, where the high (low) payoff of the risky lottery is higher (lower) than that of the safe lottery. In the first paired lottery choice the high payoff is reached with a probability of 0.10. This probability increases with 0.10 in each paired lottery choice, until the high payoff is reached with certainty in the last paired lottery choice. A subject's attitude towards risk then determines at which paired lottery choice she switches from the 'safe' lottery to the 'risky' lottery. Subjects are informed that after all subjects made all ten decisions, only one of these is selected at random and played to determine her earnings.

As an alternative measurement for attitudes towards risk, we use the thrill and adventure seeking (TAS) subscale of Zuckerman's (1994) Sensation Seeking Scale V (SSSV). This subscale examines the subject's appeal to dangerous activities or risk taking, and has been shown to correlate significantly with behavior towards risk (e.g. Zuckerman and Kuhlman, 2000; Zaleskiewicz, 2001). The data are gathered using a questionnaire containing ten forced choice items, e.g., "I often wish I could be a mountain climber" versus "I can't understand people who risk their necks climbing mountains".

Attitudes towards loss are measured using a method similar to that of Gächter et al. (2010). In our experiment, subjects face six decisions in which they can either accept or decline a lottery. Each lottery involves a 0.50 probability of winning 125 ECU, and a 0.50 probability of losing an amount ranging from 25 ECU to 150 ECU. A subject's degree of loss aversion affects which lotteries she declines. Again, only one of the subject's choices is selected at random and played to determine her earnings.

Impatience is measured by conducting the Monetary Choice Questionnaire by Kirby et al. (1999). In this questionnaire subjects have to make 27 hypothetical decisions between receiving a smaller, immediate monetary reward and a larger, delayed monetary reward. For instance, subjects may choose between receiving €20 today and €55 in seven days.

The Regret Scale of Schwartz et al. (2002) is used to assess subjects' tendency to experience regret. The scale consists of five statements, e.g., "When I think about how I'm doing in life, I often assess opportunities I have passed up". Subjects respond to these statements using a seven-point Likert-scale ranging from zero (completely disagree) to six (completely agree).

3.2.3 Procedures

Six sessions, with 132 subjects, were run in the experimental laboratory ELSE at Utrecht University in June 2012. Participating subjects came from the subject pool that mainly recruits students of Utrecht University from all faculties and study programmes (ORSEE, Greiner (2004)). The procedures during the sessions were kept constant and all sessions were computerized using the software z-Tree (Fischbacher, 2007). ELSE has 30 cubicles and connected PCs allowing computer-assisted exchange of information. At the start of the experiment, subjects were seated in random order at the computers in the laboratory. During the sessions, they were not allowed to communicate. The instructions (see Appendix B.1), available in Dutch and English, were printed and read individually. Questions about the instructions were answered by the experimenter in private. Sessions lasted approximately 90 minutes, including instructions, psychometric measures and a final questionnaire.

Following Ivanova-Stenzel and Salmon (2004a,b, 2008a,b, 2011), the experimental design consisted of two phases. In the first phase, which is referred to as the learning phase, subjects played the mechanisms for several rounds, which allowed them to determine their strategies and form preferences over the mechanisms. At the start of each round, a subject was randomly matched to another subject. Subjects did not know the identity of the other subject in their pair, neither during the experiment nor after. Each pair received a randomly determined BIN price, which was the same for both posted price and BIN auction, and all subjects received independent private values. Subjects then participated in three trading periods, where posted price, ascending auction and BIN auction were each played once and the subject pairs, values and prices were kept constant. The order in which the mechanisms were played was randomly determined and varied across sessions. After three trading periods a new round commenced, in which subjects were paired with a new subject, received a new value and a new BIN price. In total, subjects participated in four rounds, resulting in 12 trading periods in the learning phase for which they received real earnings. At the end of the learning phase subjects received information on their total earnings so far.

In the second phase, the choice phase, subjects faced a series of entry decisions. Nine choice tasks were presented, in which subjects had to choose multiple times between entering one of two mechanisms: posted price versus ascending auction, posted price versus BIN auction, and BIN auction versus ascending auction. In each choice task subjects received a list of ten randomly drawn values for which they had to decide which mechanism to enter. Before making this decision, subjects were informed about the BIN price, which was randomly drawn and constant for all subjects in the session. After all subjects reached a decision, one of the ten choices made by the subject was picked at random and was then actually played. Subjects knew that, regardless of their choice, they would always compete against one other subject. In case a certain mechanism was entered by an odd number of subjects, one of the subjects was placed in a mechanism by default. This was classified as a mismatch, and the identity of this subject was randomly decided. For each pair of mechanisms, subjects received three choice tasks. This resulted in 30 entry decisions per pair of mechanisms and nine trading periods in the choice phase. Again, the order in which the choice tasks were presented was randomly determined and varied across sessions.

After both phases finished, subjects were informed about their earnings so far. They would then take part in some additional decision tasks, during which their risk and loss attitudes were assessed. Afterwards they were informed about their final earnings and were asked to answer a questionnaire on personal data and online auction experience. This questionnaire also included the SSSV-TAS, the Monetary Choice Questionnaire and the Regret Scale. Earnings were converted to Euro at an exchange rate of 25 ECU = € 1, and were rounded up to 50 cents. Subjects who showed up late and therefore could not participate in the experiment received a show-up fee of € 3.00.

3.3 Sample

The experiment was conducted with 132 subjects, each playing 21 trading periods and making 90 entry decisions. We were unable to include the data of 16 subjects as they made inconsistent choices in the risk and/or loss assessment, which resulted in missing values. The data of two other subjects were excluded because multiple questionnaire items were answered inconsistently and because their experimental results were significantly different from the rest of the group. Our final sample consists of 114 subjects. On average, these subjects earned € 16.08, with a minimum of € 3.00 and a maximum of € 33.50.[11]

[11] The average earnings of all 132 subjects were € 15.61. Since our experimental design allowed subjects to overbid and to buy at BIN prices higher than their values, some subjects made losses during the experiment. Two subjects made an overall loss (of € 5.00 and € 3.50, respectively), but nevertheless received the show-up fee of € 3.00. Subjects were not aware of this show-up fee and were warned about making losses in the instructions. The two subjects who made an overall loss were not included in the final sample due to missing values. On average, the 114 remaining subjects made 0.289 losses. Whereas some of these subjects made up to three losses, the majority of subjects (79%) made no losses at all.

Table 3.1: Descriptive statistics concerning subjects

	N	Mean	SD	Min	Max
1. Gender[1]	114	0.561	0.498	0	1
2. Age	114	23.158	3.769	17	43
3. Nationality[2]	114	0.605	0.491	0	1
4. Students[3]	114	0.877	0.330	0	1
5. Economics[4]	114	0.333	0.473	0	1
6. Online auction[5]	114	0.421	0.496	0	1
7. Payoffs P[6]	114	37.886	46.484	-73	153
8. Payoffs A[6]	114	70.272	51.046	-89	248
9. Payoffs BIN[6]	114	65.605	43.864	0	199
10. Impatience	114	-5.056	2.018	-10.820	-0.693
11. Risk attitude	114	6.272	1.576	1	9
12. Loss attitude	114	5	1.234	1	7
13. Sensation seeking	114	6.439	2.380	0	10
14. Regret	114	16.404	6.349	0	29

[1] Female=1, male=0.
[2] Dutch=1, non-Dutch=0.
[3] Student=1, non-student=0.
[4] Economics student=1, other=0.
[5] Experience=1, no experience=0.
[6] Payoffs from trading periods played during the learning phase.

Table 3.1 provides descriptive statistics about our subjects. The first part of the table gives demographic information about our subjects. Approximately 56% of our subjects were female, 61% had the Dutch nationality and on average they were 23 years old. A majority of our subjects were students (88%) and one third studied economics. 42% of our subjects participated in an online auction before.

The second part of Table 3.1 provides some information about subjects' performances in the learning phase of the experiment. On average, subjects earned 38 ECU by buying at a posted price (P), 70 ECU in the ascending auction (A), and 66 ECU in the BIN auction (BIN).

The third part of Table 3.1 describes the psychometric variables measured during the experiment. Subjects' responses to the Monetary Choice Questionnaire are transformed into discount rates using a technique introduced by Wileyto et al. (2004). Impatience is then recorded as the natural log of these discount rates, which is on average -5.056. This corresponds to a discount rate of 0.0064 and indicates a relative lack of discounting. Using the method of Holt and Laury (2002), risk attitudes are classified into nine risk categories, ranging from highly risk loving to extremely risk averse. The subjects in our experiment are on average risk averse. Loss attitudes range from 1 (accept all lotteries) to 7 (reject all lotteries). On average, subjects accept all lotteries up to the point where potential gains equal potential losses. This suggests that subjects are on average neutral towards losses. Sensation Seeking scores (Cronbach's alpha of 0.679) may range from 0 to 10 points, with 10 being highly sensation seeking. Subjects in our experiment have on average lower scores (6.439) than the normative sample from Zuckerman (1994) (7.01), when corrected for the ratio of women and men. This is consistent with our finding that subjects are on average risk averse. Regret scores are taken from the Regret Scale (Cronbach's alpha of 0.804) and may range from 0 to 30, with 30 being highly sensitive to feelings of regret. On average our subjects seem to be only somewhat sensitive to feelings of regret (16.404).

Table B.6 in Appendix B.2 reports the pairwise correlations of the variables introduced in this section. Although previous research has shown that sensation seeking is related to risk taking behavior (e.g. Zuckerman and Kuhlman, 2000; Zaleskiewicz, 2001), we find that the correlation between risk attitudes as elicited in the Holt and Laury task and sensation seeking as measured by the SSSV-TAS is not significant.[12] Several other studies have reported that different measures of risk attitudes are uncorrelated. For instance, Eckel and Wilson (2004) also find no clear evidence for a correlation between outcomes of the Holt and Laury task and the SSSV-TAS.[13] Other studies test the relationship between the Holt and Laury task and the full scale of the SSSV, and only find a weak correlation (e.g. Eckel and Wilson, 2004; Rosenkranz and Weitzel, 2012). These findings may be explained in two ways. First, the predictive validity of expected utility-based assessments of risk attitudes is questionable when decisions concern low stakes (Harrison et al., 2005), as is the case in the Holt and Laury task as implemented in our experiment. Second, the two variables measure different aspects related to risk attitudes. Whereas the Holt and Laury task measures risk taking propensity directly, sensation seeking measures personality traits associated with risk taking.

3.4 Results

This section contains a discussion of our results. Section 3.4.1 provides an overview of subjects' buying and bidding behavior within the various

[12]Note that an increase in risk attitude corresponds to a subject being more risk averse, whereas an increase in sensation seeking corresponds to a subject being more willing to participate in dangerous activities or risk taking. We would therefore expect to see a negative correlation between risk attitudes and sensation seeking.

[13]Over all treatments, Eckel and Wilson (2004) find no evidence for a significant correlation between risk attitudes as elicited in the Holt and Laury task and sensation seeking as measured by the SSSV-TAS. Only for one out of three treatments, they find a statistically significant but weak correlation.

selling mechanisms. Section 3.4.2 contains a descriptive analysis of subjects' entry decisions. It provides information about which selling mechanisms are preferred by subjects in general and identifies patterns in how entry decisions are made. Section 3.4.3 further analyzes the determinants of entry decisions. More specifically, it examines whether entry decisions are determined by monetary and/or non-monetary incentives.

3.4.1 Buying and bidding within selling mechanisms

To better understand subjects' preferences over selling mechanisms, we start by taking a closer look at their behavior within the selling mechanisms. Recall that subjects participated in 21 trading periods in total. In the learning phase, each subject participated in each of the three mechanisms four times; in the choice phase, each subject participated in nine mechanisms of her own choice. Table 3.2 provides descriptive statistics concerning the selling mechanisms played in the experiment, divided into those mechanisms played in the learning phase and those played in the choice phase. We look at three variables: average payoff to subjects, revenue and efficiency. The first variable, average payoff to subjects, is measured as the winner's payoff divided by the number of subjects in the mechanism. Revenue is measured as the payment by the winning subject, and efficiency is measured as the percentage of mechanisms that is won by the subject with the highest value.[14,15]

[14]Kruskal-Wallis tests are conducted to evaluate differences in these variables across mechanisms in the learning phase. The tests, corrected for tied ranks, show that average payoff to subjects ($\chi^2(2, N{=}591) = 54.806$, $p = 0.0001$) and efficiency ($\chi^2(2, N{=}591) = 22.793$, $p = 0.0001$) differ significantly across mechanisms. Revenue does not differ significantly across mechanisms in the learning phase ($\chi^2(2, N{=}591) = 0.932$, $p = 0.6275$). To evaluate pairwise differences between the three mechanisms we conduct post-hoc tests, controlling for Type I error across tests by using a Bonferroni correction. Mann-Whitney tests reveal significant differences between posted price and the other mechanisms for average payoff to subjects (P vs. A (z = -6.764, p = 0); P vs. BIN (z = -5.910, p = 0)) and efficiency (P vs. A (z = -4.571, p = 0); P vs. BIN (z = -3.279, p = 0.001)). We do not find significant differences between ascending auction and BIN auction for both average payoff to subjects (z = 1.289, p = 0.1973) and efficiency (z = 1.325, p = 0.1853).

[15]In the choice phase, we use Mann-Whitney tests and find that efficiency significantly differs across mechanisms (P vs. A (z = -2.413, p = 0.0158); P vs. BIN (z = -2.699, p = 0.0069); A vs. BIN (z = 4.309, p = 0)). We further find that average payoff to subjects is significantly higher in posted price than in ascending auction (z = 4.096, p = 0) and BIN auction (z = 3.740, p = 0.0002), but not significantly different for the two auctions (z = -1.054, p = 0.2917). This is not surprising, as in Section 3.4.2 we show that subjects with higher values are more likely to enter the posted price than an alternative mechanism, thereby leading to higher payoffs. For the same reason, revenue is significantly higher in posted price than in ascending auction (z = 3.067, p = 0.0022). No significant differences are found between posted price and BIN auction (z = -0.875, p = 0.3818), or ascending auction and BIN auction (z = 0.075, p = 0.9400).

Table 3.2: Descriptive statistics concerning selling mechanisms

	Times played†	Avg payoff to subjects	Revenue	Efficiency
Learning phase				
Posted price	197	9.556	28.898	0.513
Ascending auction	197	17.985	25.015	0.736
BIN auction	197	16.586	26.178	0.675
Choice phase				
Posted price	51	20.529	32.882	0.588
Ascending auction	91	12.890	23.253	0.780
Posted price	30	20.450	27.767	0.500
BIN auction	114	11.140	28.447	0.754
BIN auction	74	18.122	30.851	0.608
Ascending auction	71	15.732	27.380	0.915

† Games in which one of the subjects was forced into the mechanism or which involved one of the 18 excluded subjects were excluded from consideration.

We find that subjects make very fast decisions when buying at posted prices: 83% of all buys are made within 3 seconds after the start of the trading period, and 92% are made within 5 seconds. This is most likely due to the first-come, first-served rule implemented in the experiment, which may additionally explain efficiency levels close to 50%. Furthermore, because of the existence of a positive BIN price, a good may not be sold in the posted price, even though subjects may have a positive value for it. Indeed, we observe that if subjects cannot opt out of the mechanism, as is the case in the learning phase, nothing is sold in 27% of all trading periods. This is in line with the lower average payoff to subjects in the posted price compared to other mechanisms in the learning phase reported in Table 3.2.

Recall that the auctions have a fixed deadline and require subjects to place bids manually. For that reason, the bidding process in our auctions differs substantially from the one in English auctions (Isaac et al., 2007). In ascending auctions, we observe both jump bidding and last-minute bidding. On average, each subject submits 1.86 bids per trading period. More than half (52%) of winning bids are placed within less than 5 seconds of the end of the auction. These bidding strategies may explain the rather low levels of efficiency reported in Table 3.2—in English or ascending clock auctions without a fixed deadline, efficiency levels close to 100% are not unusual (e.g. Ivanova-Stenzel and Salmon, 2011).

To get some more insight into subjects' bidding strategies, we compare their bids to those predicted by auction theory. Due to the installment of a fixed deadline and due to the occurrence of jump bidding and last-minute bidding, the equilibrium bidding strategy for English auctions does not provide a good benchmark for bidding in our ascending auctions. Placing a last-minute bid, however, to some extent resembles placing a bid in a first-price auction. Avery (1998) finds that the greater the importance for jump bidding, the more an ascending auction resembles a first-price auction. We may therefore use the Risk Neutral Nash Equilibrium (RNNE) bidding strategy for first-price auctions as a benchmark for actual bidding behavior in the experiment.

The RNNE bidding strategy for a bidder with value v, who participates in a first-price auction with $N = 2$ bidders and where values are uniformly distributed between 0 and 100, is given by $b(v) = \frac{v}{2}$ (e.g. Milgrom and Weber, 1982; Kagel and Levin, 1993). We use the values of the winning bidders to calculate the corresponding RNNE winning bids, and compare this to subjects' actual winning bids. We observe both upward and downward deviations from the RNNE in the experiment. In the learning phase, the actual winning bid is on average equal to 25.015, whereas the RNNE winning bid is on average equal to 30.492. A Wilcoxon signed-ranks test indicates that this difference in bidding is statistically significant ($z = -4.826$, $p = 0$). In the choice phase, however, we find no difference between actual winning bids and RNNE winning bids.[16] It seems that many of the underbidding subjects select out of the ascending auction when they have the chance.[17] This finding suggests that the bidding strategies used in ascending auctions in the choice phase approach the RNNE bidding strategy in first-price auctions. In Section 3.4.3, we therefore use the RNNE bidding strategy to calculate the expected payoffs of bidding.

In BIN auctions, we observe both fast buying decisions, as well as jump bidding and last-minute bidding. Overall, subjects select the BIN option in 54% of all trading periods. When examining the choice between bidding and buying within a BIN auction for the two phases of the experiment separately, we find that the way this mechanism is used differs substantially across phases. In the learning phase, subjects select the BIN option in roughly 53% of the trading periods involving the BIN auction. When subjects are given the choice between posted price and BIN auction, only

[16]In the choice phase, the RNNE bidding strategy is still given by $b(v) = \frac{v}{2}$. Though we later show that subjects follow a cut-off strategy based on their values when entering mechanisms, subjects may reasonably assume that the values of competing subjects in the auctions are uniformly distributed and that the lowest possible value is equal to 0. We find that, for the choice between posted price and ascending auction, the actual winning bid is on average equal to 23.253, whereas the RNNE winning bid is on average equal to 24.516. This difference is not statistically significant (z = -1.188, p = 0.235). For the choice between BIN auction and ascending auction, the actual winning bid is on average equal to 27.380, whereas the RNNE winning bid is on average equal to 29.423. This difference is also not statistically significant (z = -1.287, p = 0.198).

[17]Such a selection effect may be based on subjects' values or on their characteristics. For instance, we later show that more risk averse subjects enter the ascending auction more often. In the first-price auction, a greater degree of risk aversion leads to higher bids.

Table 3.3: Frequency table concerning entry decisions

	All Data		Value ≤ BIN price		Value > BIN price	
	Freq.	Percent	Freq.	Percent	Freq.	Percent
Posted price	1338	39.12%	102	6.75%	1236	64.75%
Ascending auction	2082	60.88%	1409	93.25%	673	35.25%
Posted price	877	25.64%	121	6.32%	756	50.27%
BIN auction	2543	74.36%	1795	93.68%	748	49.73%
BIN auction	1699	49.68%	439	25.66%	1260	73.73%
Ascending auction	1721	50.32%	1272	74.34%	449	26.27%

34% of the subsequently played BIN auctions are won by a subject selecting the BIN option. However, when subjects are given the choice between BIN auction and ascending auction, 85% of the subsequently played BIN auctions are won by a subject selecting the BIN option. This suggests that the BIN auction is mainly *used to bid* if the alternative mechanism in the entry decision involves buying immediately; it is mainly *used to buy* if the alternative mechanism involves bidding. Furthermore, we observe that if subjects select the BIN option, this is often done immediately. Only 6% of all BIN decisions are made after observing at least one bid. These findings suggest that the BIN auction is used as an alternative to posted price or ascending auction, rather than as a hybrid mechanism in which subjects only buy after a certain threshold has been reached.

3.4.2 Entry decisions

In the choice phase of our experiment, subjects were required to choose between entering one mechanism versus an alternative mechanism. This entry decision is the main interest of our analysis, and is recorded as a binary variable where 0 represents a subject choosing one mechanism and 1 represents the subject choosing an alternative mechanism. Because in each choice task subjects had to choose between two mechanisms, our analysis deals with each pair of mechanisms separately. Furthermore, as each of the 114 subjects made 30 entry decisions per pair of mechanisms, our analysis consists of 3420 entry decisions per pair of mechanisms.

We start by examining which selling mechanisms are preferred by subjects in general. An overview of how often a certain mechanism is chosen can be found in Table 3.3. Using a Chi-square goodness of fit test, we find that subjects enter the posted price significantly less often than the ascending auction ($\chi^2(1, N{=}3420) = 161.85$, $p = 0$) or the BIN auction ($\chi^2(1, N{=}3420) = 811.57$, $p = 0$). There is no difference in entry frequencies for the choice between ascending and BIN auction ($\chi^2(1, N{=}3420) = 0.14$, $p = 0.7068$).

As a first step toward investigating how subjects decide which mechanism to enter, we divide our data in two sets. The first set consists of entry decisions for which subjects' values are smaller than or equal to BIN prices. For these values buying at the BIN price will never be profitable; only bidding may lead to positive payoffs. The second set consists of entry decisions for which subjects' values are greater than BIN prices. For these values both bidding and buying may generate positive payoffs. The corresponding entry frequencies can be found in Table 3.3. We find that for values smaller than or equal to BIN prices, most subjects prefer to enter the ascending auction over the posted price and BIN auction, and prefer to enter the BIN auction over the posted price. Conversely, for values greater than BIN prices, most subjects prefer to enter the posted price over the ascending auction, and prefer to enter the BIN auction over the ascending auction.[18]

A graphical depiction of this finding is shown in Figure 3.1, which displays the distribution plots of the difference between subjects' values and BIN prices of subjects choosing a certain mechanism. Notice that these distributions are skewed to the left for mechanisms which involve buying, whereas these distributions are skewed to the right for mechanisms which involve bidding. This confirms that for values below BIN prices subjects mainly enter mechanisms which involve bidding; for values above BIN prices subjects mainly enter mechanisms which involve buying.

It is remarkable that some subjects still choose to enter a mechanism which involves buying, even when selecting the BIN option can never generate positive payoffs. We find that when subjects have values lower than or equal to the BIN price, roughly 7% and 6% of all entry decisions are made in favor of the posted price over the ascending and BIN auction, respectively. Likewise, 26% of entry decisions are made in favor of the BIN auction over the ascending auction.[19] Of course, in BIN auctions subjects with values smaller than or equal to BIN prices can still generate positive payoffs by bidding for the good. However, for these subjects the probability of winning a BIN auction is smaller than the probability of winning an as-

[18] Chi-square tests confirm that the difference in entry frequencies between the two sets is statistically significant for all pairs of mechanisms: posted price vs. ascending auction ($\chi^2(1,\ N{=}3420) = 1.2\text{e}{+}03,\ p = 0$), posted price vs. BIN auction ($\chi^2(1,\ N{=}3420) = 853.602,\ p = 0$), and BIN auction vs. ascending auction ($\chi^2(1,\ N{=}3420) = 790.294,\ p = 0$).

[19] Chi-square goodness of fit tests show that entry frequencies into the posted price are significantly higher than 0% when subjects have values smaller than or equal to the BIN price, both for posted price vs. ascending auction ($\chi^2(1,\ N{=}1511) = 6.89,\ p = 0.0087$), and for posted price vs. BIN auction ($\chi^2(1,\ N{=}1916) = 7.64,\ p = 0.0057$). The same holds for the BIN auction when subjects choose between the BIN and ascending auction ($\chi^2(1,\ N{=}1711) = 112.64,\ p = 0$).

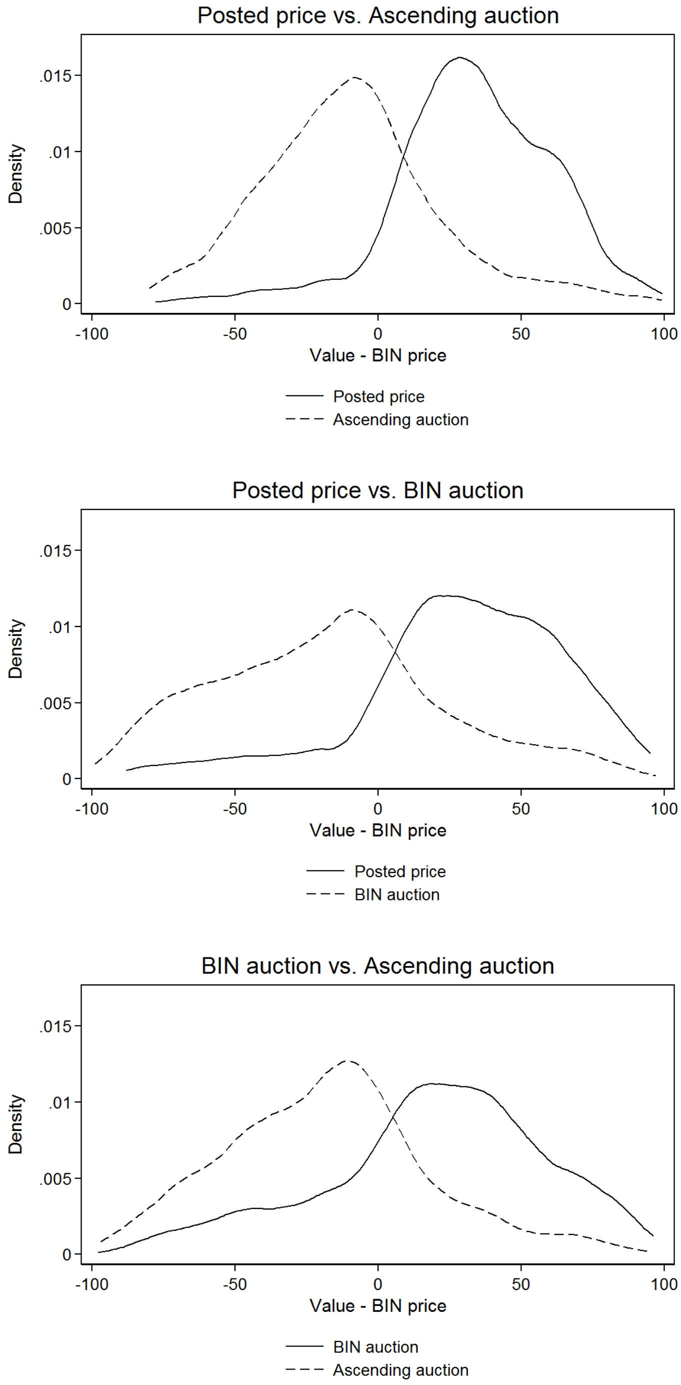


Figure 3.1: Distribution plots of the difference between values and BIN prices of subjects choosing a certain mechanism

Table 3.4: Frequency table concerning the number of times a subject switches between mechanisms per choice task

Number of switches	P vs. A Freq.	P vs. A Percent	P vs. BIN Freq.	P vs. BIN Percent	BIN vs. A Freq.	BIN vs. A Percent
0	86	25.15%	194	56.73%	138	40.35%
1	238	69.59%	140	40.94%	195	57.02%
≥2	18	5.26%	8	2.33%	9	2.63%

cending auction, as a competitor may stop the BIN auction at any time by selecting the BIN option. When taking a closer look at the buying behavior of subjects in the choice phase, we find that hardly any of the subjects with values smaller than or equal to BIN prices selects the BIN option.[20] This suggests that some subjects dislike bidding to such an extent that they are willing to give up their chance of winning the good and thereby of receiving a positive payoff.

To gain further insight into how entry decisions are made, we examine choice behavior on an individual level. We find that some subjects have a strong bias towards one of the mechanisms. For the choice between posted price and ascending auction, only one of 114 subjects exclusively chose the posted price, whereas six exclusively chose the ascending auction. For the choice between BIN auction and ascending auction we observe similar numbers. Six subjects exclusively chose the BIN auction and five exclusively chose the ascending auction. Surprisingly, for the choice between posted price and BIN auction as many as 38 subjects exclusively chose the BIN auction. This suggests that the BIN auction is often used as an alternative to posted price, which is consistent with the observed behavior in this mechanism (see Section 3.4.1).

Recall that during the experiment each of the 114 subjects was presented with three choice tasks for each of the pairs of mechanisms. As a result, we have data on 342 choice tasks per pair of mechanisms. Each choice tasks contained ten entry choices for ten different values, sorted in ascending order, and a single BIN price. Table 3.4 reports how often a subject switches between mechanisms in a given choice task.[21] It can be

[20]For instance, for the choice between posted price and ascending auction, only 1 of the subjects with a value smaller than or equal to the BIN price bought in the posted price. This subject had a value equal to the BIN price and did therefore not incur a loss. For the choice between BIN and ascending auction, 2 of the subjects with values smaller than or equal to the BIN price bought at the BIN price. They incurred losses of -38 and -23 ECU, respectively. For the choice between posted price and BIN auction, 1 subject bought in the posted price and 5 subjects bought in the BIN auction. They all incurred substantial losses.

[21]Recall that in our experiment subjects always had to make an entry decision. In-

seen that there are quite some choice tasks for which subjects do not switch between mechanisms. In most choice tasks subjects switch exactly once. This suggests that, like in Ivanova-Stenzel and Salmon (2011), many subjects follow a cut-off strategy. At values below some cut-off subjects choose one mechanism (typically one that involves bidding), and at values above this cut-off subjects choose another mechanism (typically one that involves buying). The level of the cut-off most likely depends on the BIN price. In the next section, we present a more sophisticated empirical analysis of how subjects decide which mechanism to enter.

3.4.3 Determinants of entry

Our next aim is to analyze whether and how entry decisions are affected by monetary and non-monetary incentives. Monetary incentives are given by the expected payoffs of buying versus bidding. Non-monetary incentives include impatience, risk attitudes, loss attitudes, sensation seeking and regret, which are measured in the way described in Section 3.3. We further test if entry decisions are affected by control variables such as gender, age, nationality, and whether or not subjects are students, study economics and have experience with bidding in online auctions. Finally, we control for subjects' payoffs in the mechanisms in the learning phase.

The expected payoffs of buying versus bidding are calculated as follows. Recall that in our experiment, the first subject to select the BIN option wins and receives a payoff equal to her value (v) minus the BIN price (p). As there are $N = 2$ subjects in each trading period, a subject deciding whether or not to enter a mechanism involving buying does not know beforehand whether she will obtain a positive payoff. Though some subjects may have private beliefs about their ability to be faster than others, we assume that all subjects are equally likely to be the first in selecting the BIN option. Hence, the expected payoffs of buying for a subject with value v are given by $\left(\frac{1}{2}\right)(v - p)$. In Section 3.4.1, we showed that the bidding strategies used in the choice phase of our experiment approach the RNNE bidding strategy in first-price auctions, i.e., $b(v) = \frac{v}{2}$. We therefore use this bidding strategy to calculate the expected payoffs of bidding. From auction theory, we know that if subjects' values are uniformly distributed between 0 and 100, expected payoffs for a subject with value v in a first-price auction with $N = 2$ subjects are equal to $\left(\frac{v}{100}\right)(v - b(v))$. Hence, the expected payoffs of bidding are given by $\frac{1}{200}v^2$.

The effect of monetary incentives on entry decisions is measured in two ways. First, we analyze the effect of differences in expected payoffs

difference would thus only be noticed by seemingly random behavior.

by including the binary variable Buy vs. Bid, which is equal to 0 if the expected payoffs of buying are greater than those of bidding, and equal to 1 otherwise. We expect that this variable positively affects the likelihood of entering a mechanism involving bidding. Second, we analyze the effect of absolute expected payoffs by including subjects' values and BIN prices separately in our analysis. We expect that the likelihood of entering a mechanism involving bidding is increasing in the BIN price. Furthermore, we expect a nonlinear effect of values. That is, both subjects with very low and very high values may prefer bidding in an auction over buying at a posted price, either because they cannot obtain positive payoffs by buying or because they can increase their chances of winning by placing a high bid. From the expected payoffs of buying versus bidding, we expect that an increase in values increases the likelihood of entering a mechanism involving bidding for values up to 50; it decreases this likelihood for values greater than 50.[22]

In order to analyze the impact of monetary, non-monetary and control variables on subjects' entry decisions, we estimate six panel logit models with random effects—for each of the pairs of mechanisms we estimate one model including differences in expected payoffs and one including absolute expected payoffs. We use this model to accommodate for the fact that we have a panel data set with 114 subjects, who each make a series of binary entry decisions, and because non-monetary and control variables are constant over time. Table 3.4.3 shows the results of the random effects logit regressions, with standard errors clustered at the subject level, for each pair of mechanisms separately. Columns (I) and (II) report the results for entry decisions between posted price and ascending auction, columns (III) and (IV) for posted price and BIN auction, and columns (V) and (VI) for BIN auction and ascending auction.

We find that subjects are more likely to enter those mechanisms which give the highest relative as well as absolute expected payoffs. This indicates that monetary incentives affect subjects' entry decisions. Columns (I), (III) and (V) report the effects of differences in expected payoffs, and show that the variable Buy vs. Bid has a highly statistically significant and positive effect on entry decisions for all pairs of mechanisms. Thus, if the expected payoffs of buying are greater than those of bidding, subjects are more likely to enter the posted price than the ascending or BIN auction. Furthermore, subjects are more likely to enter the BIN auction than the ascending auction. Conversely, if the expected payoffs of bidding are greater than those of buying, subjects are more likely to enter the ascending auction

[22] The expected payoffs of buying minus the expected payoffs of bidding are given by $\frac{1}{2}\left(v - \frac{1}{100}v^2 - p\right)$. This expression is decreasing in p and follows an inverted U-shape in v with a maximum at $v = 50$.

	P vs. A		P vs. BIN		BIN vs. A	
	(I)	(II)	(III)	(IV)	(V)	(VI)
Buy vs. Bid	2.396***		1.873***		2.397***	
	(0.415)		(0.326)		(0.269)	
BIN price		0.0663***		0.0512***		0.0440***
		(0.00967)		(0.00976)		(0.00539)
Value		-0.0466***		-0.0608***		-0.0240**
		(0.0165)		(0.0154)		(0.00958)
Value^2		-0.000102		0.000108		-9.26e-05
		(0.000125)		(0.000113)		(8.90e-05)
Impatience	-0.0701	-0.167**	-0.0379	-0.0924	-0.212***	-0.269***
	(0.0555)	(0.0707)	(0.120)	(0.143)	(0.0772)	(0.0966)
Risk attitude	0.0781	0.149*	0.250*	0.316**	0.125	0.182*
	(0.0669)	(0.0798)	(0.129)	(0.150)	(0.0812)	(0.102)
Loss attitude	-0.194**	-0.175	-0.194	-0.158	-0.0994	-0.126
	(0.0860)	(0.110)	(0.211)	(0.260)	(0.0974)	(0.125)
Sensation seeking	0.0214	0.0453	0.102	0.0949	0.113*	0.160**
	(0.0550)	(0.0653)	(0.107)	(0.132)	(0.0624)	(0.0784)
Regret	0.0132	0.0161	-0.0178	-0.0196	0.0374	0.0449
	(0.0170)	(0.0197)	(0.0322)	(0.0399)	(0.0248)	(0.0313)
Gender	-0.489**	-0.866***	-1.000**	-1.643**	-0.464*	-0.646*
	(0.247)	(0.322)	(0.496)	(0.638)	(0.279)	(0.355)
Age	-0.0200	-0.0344	0.0962	0.133	-0.0341	-0.00569
	(0.0299)	(0.0376)	(0.0725)	(0.0886)	(0.0446)	(0.0539)
Nationality	-0.0243	-0.0191	0.822	1.112*	-0.165	-0.354
	(0.280)	(0.353)	(0.527)	(0.648)	(0.298)	(0.367)
Students	0.231	0.563	0.105	0.593	-0.0143	0.347
	(0.348)	(0.515)	(0.869)	(0.987)	(0.501)	(0.595)

Economics	-0.103	-0.134	0.213	0.388	-0.260	-0.416
	(0.298)	(0.378)	(0.568)	(0.678)	(0.325)	(0.414)
Online auction	0.0666	0.104	0.403	0.218	0.180	0.196
	(0.233)	(0.290)	(0.466)	(0.562)	(0.270)	(0.335)
Payoffs P	-0.00338	-0.00393	-0.00915*	-0.00889	-0.00132	-0.00223
	(0.00238)	(0.00318)	(0.00520)	(0.00642)	(0.00318)	(0.00383)
Payoffs A	0.00264	0.00409	0.0107**	0.0130**	0.00272	0.00324
	(0.00256)	(0.00297)	(0.00511)	(0.00630)	(0.00291)	(0.00355)
Payoffs BIN	-0.000627	0.000840	0.000109	-0.000182	-0.000691	-0.000182
	(0.00324)	(0.00422)	(0.00600)	(0.00749)	(0.00481)	(0.00618)
Constant	-1.217	-0.0988	-3.377	-3.229	-3.559*	-3.933
	(1.564)	(1.825)	(3.056)	(3.662)	(2.043)	(2.437)
Observations	3,420	3,420	3,420	3,420	3,420	3,420
Number of Subject	114	114	114	114	114	114
LL	-1978	-1378	-1380	-1043	-1826	-1575
Prob > chi2	8.10e-06	9.64e-10	4.09e-07	0.000272	0	1.19e-10

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.5: Random effects logit panel regression examining entry decisions between posted price and ascending auction (where 0=P and 1=A), posted price and BIN auction (where 0=P and 1=BIN), and BIN auction and ascending auction (where 0=BIN and 1=A)

than the posted price or BIN auction, and are more likely to enter the BIN auction than the posted price.

Columns (II), (IV) and (VI) report the effects of absolute expected payoffs on entry decisions. As expected, an increase in the BIN price significantly and positively affects the likelihood of entering a mechanism involving bidding. That is, for high BIN prices subjects are more likely to enter the ascending auction than the posted price and BIN auction, and more likely to enter the BIN auction than the posted price. We further find that values have a statistically significant and negative effect on the likelihood of entering a mechanism involving bidding. We control for non-linear effects by adding the square of the values, but find no effect. Thus, for a given BIN price, an increase in values makes subjects more likely to enter the posted price than the ascending or BIN auction, and makes them more likely to enter the BIN auction than the ascending auction. This is in line with our finding that subjects use a cut-off strategy when making entry decisions (see Section 3.4.2).

Non-monetary incentives also affect subjects' entry decisions. We find strong evidence that impatience decreases the likelihood of entering an ascending auction for the choice between the BIN and ascending auction. An explanation for this lies in the fact that the ascending auction is the only mechanism that always lasts 45 seconds—it cannot be ended early by selecting the BIN option. We also find some evidence that impatience decreases the likelihood of entering the ascending auction for the choice between the posted price and ascending auction, when we control for absolute expected payoffs. However, this effect disappears when we control for differences in expected payoffs.

Furthermore, Table 3.4.3 indicates a positive relationship between risk attitudes as elicited in the Holt and Laury task[23] and the likelihood of entering a mechanism involving bidding. When controlling for absolute expected payoffs, an increase in risk aversion leads to an increase in the likelihood of entering the ascending auction when it is compared to the posted price or BIN auction, and to an increase in the likelihood of entering the BIN auction when it is compared to the posted price. When controlling for differences in expected payoffs, we only find such an effect for the choice between posted price and BIN auction. We also find some evidence that an increase in sensation seeking leads to an increase in the likelihood of entering the ascending auction when it is compared to the BIN auction. This effect moves in the opposite direction of the effect of risk attitudes as elicited in the Holt and Laury task. An explanation for these opposing effects may

[23] Recall that an increase in risk attitude corresponds to a subject being more risk averse.

be based on the experimental design decisions made in our study. Recall that a first-come, first-served rule was implemented for selecting the BIN option. For this reason, the level of risk in posted price and BIN auction is substantial. In fact, it may even be less risky for a subject to place a high bid in an ascending auction. It is then perhaps not a surprise that an increase in risk aversion as measured by the Holt and Laury task leads subjects away from mechanisms involving buying. Sensation seeking, on the contrary, does not directly measure risk taking propensity, but rather measures personality traits associated with risk taking. These traits may play a role in entry decisions independent of risk attitudes. For instance, the thrill of competing in an auction may be severely reduced when there is a possibility that the good is taken away by a competitor selecting the BIN option.

We do not find strong evidence for an effect of loss attitudes.[24] The effect is insignificant for all specifications but for the one reported in column (I), where subjects choose between posted price and ascending auction and we control for differences in expected payoffs. For this specification, we find that more loss averse subjects are more likely to enter the posted price. There is no evidence for an effect of regret.

Concerning the demographic variables, we find a strong evidence for the existence of gender difference in entry decisions, but find no effect of the other demographic variables.[25] Whereas females are more likely to enter a mechanism involving buying, males are more likely to enter a mechanism involving bidding. This finding is in line with previous studies, which find that females shy away from competition (e.g. Gneezy et al., 2003; Gneezy and Rustichini, 2004; Niederle and Vesterlund, 2007; Aycinena et al., 2015). Experimental studies additionally show that females are more likely to overbid in first-price auctions than males (e.g. Ham and Kagel, 2006; Chen et al., 2013; Pearson and Schipper, 2013). As bidding in our auctions resembles bidding in first-price auctions, this may be another factor explaining why females are less likely to enter mechanisms involving bidding.

There is no strong evidence that subjects' previous earnings affect their entry decisions. Subjects' payoffs earned in the learning phase do not have an effect on entry decisions for the choices between posted price and ascending auction and between BIN and ascending auction. However, for the choice between posted price and BIN auction, an increase in the payoffs earned in the ascending auction during the learning phase increases the likelihood of entering the BIN auction. We additionally find a weakly significant effect of the payoffs earned in the posted price during the learning

[24] An increase in loss attitude corresponds to a subject being more loss averse.

[25] We only find a weakly significant positive effect of nationality on the likelihood of entering the BIN auction in column (IV).

phase, where an increase in these payoffs increases the likelihood of entering the posted price.

3.5 Conclusion

This study investigates entry decisions between three selling mechanisms. Bidding in an ascending auction and buying at a posted price are compared to a third mechanism which combines the two: the Buy-It-Now auction. We examine which selling mechanism is preferred by subjects in general, and additionally investigate how subjects make entry decisions. In doing so, our exploratory experiment involves subjects making a series of entry decisions between three pairs of selling mechanisms. That is, subjects choose between posted price and ascending auction, between posted price and Buy-It-Now auction, and between Buy-It-Now auction and ascending auction. In our experimental design, we give high priority to external validity and model the selling mechanisms after those found on the Internet. This means that mechanisms have a fixed deadline and that subjects can place bids manually in the auctions. Furthermore, we consider a permanent Buy-It-Now option, where the first subject to select this option in the posted price or Buy-It-Now auction wins the good with certainty. To examine whether and how subjects' entry decisions are affected by monetary and non-monetary incentives, we control for expected payoffs of buying versus bidding and for a wide range of consumer characteristics. To measure the latter, our experiment includes a risk attitude elicitation task, a loss attitude elicitation task, and a questionnaire measuring impatience, sensation seeking and regret.

We find that subjects enter the posted price considerably less often than the auctions. Furthermore, our results indicate that both monetary and non-monetary incentives play a role in entry decisions. We find that subjects use a cut-off strategy when making entry decisions. For a given Buy-It-Now price, subjects are more likely to enter a mechanism which involves bidding when values are below some cut-off, and more likely to enter a mechanism which involves buying when values are above this cut-off. We further find that impatience has a negative impact on the likelihood of entering a mechanism that involves bidding, whereas risk attitude, as elicited in the Holt and Laury task, has a positive impact on the likelihood of entering such a mechanism. We also find strong evidence that gender is an important factor in explaining entry decisions. Females are more likely to enter a mechanism involving buying, and males are more likely to enter a mechanism involving bidding.

To a large extent, these findings are consistent with the literature on entry decisions into auctions and other competitive environments. For instance, we confirm the use of cut-off strategies in entry decisions (e.g. Ivanova-Stenzel and Salmon, 2011), and find additional evidence in support of the claim that females shy away from competition (e.g. Niederle and Vesterlund, 2007). The impact of risk attitudes on entry decisions may at first sight seem to contradict previous results. The findings of Pevnitskaya (2004) and Palfrey and Pevnitskaya (2008) suggest that risk tolerant subjects are more likely to enter mechanisms involving bidding and that risk averse subjects are more likely to enter mechanisms involving buying. In our experiment, we find exactly the opposite. That is, for risk attitudes as elicited in the Holt and Laury task, we find that risk averse subjects are more likely to enter mechanisms involving bidding. An explanation for this lies in the experimental design decisions we made. In the real world, choosing to buy at a posted price is not nearly as risky as in our experimental design. In the literature, this is reflected in the assumption that buying at a posted price is completely safe. The outside option in the study of Palfrey and Pevnitskaya (2008), for instance, is a certain payoff that subjects receive when not participating in the auction. In our experiment, however, only a single unit of a good is sold in each selling mechanism, thereby giving only one subject a shot at receiving a positive payoff. As the first subject to select the Buy-It-Now option wins the good with certainty, entering a posted price or Buy-It-Now auction involves a substantial amount of risk. As a result, a subject who wants to avoid taking risk, may be better off placing a very high bid in an ascending auction.

Our findings suggest that sellers should take into account how potential consumers' entry decisions may be affected by the selling mechanism selected, since the format of the selling mechanism itself will affect both how many consumers and which types of consumers enter a certain selling mechanism. This, in turn, may have an effect on sellers' revenues.

Future research may examine whether the findings in our experiment are robust to changes in the experimental design. An interesting extension to our research would be to allow more than two subjects to compete in a mechanism and, hence, allow for entry coordination. By allowing for such coordination, subjects do not only need to consider their own potential payoffs and preferences, but also need to take into account the number of competitors they might encounter after entering a certain mechanism. The results of this exercise may then provide insights into which mechanism generates the highest revenue to sellers and with this add to the existing literature on revenue rankings.

Chapter 4

Social comparison concerns in auctions

4.1 Introduction

Anyone who has ever participated in a competition will probably recognize the tendency to compare one's own achievements to those of others. This tendency is commonly referred to as the 'concern for social comparison' and it has been shown to affect decision making in various economic and social contexts. Auctions are known as notoriously competitive economic decision contexts, as bidders by definition compete with others to buy a scarce good. In an online survey, Ariely and Simonson (2003) uncover that three quarters of survey respondents perceive other bidders as competitors and refer to auction outcomes as winning or losing. As a result, auctions may trigger emotional responses not present in other selling mechanisms such as posted price mechanisms (e.g. Fliessbach et al., 2007; Delgado et al., 2008; Astor et al., 2013; van den Bos et al., 2013a,b). At the same time, experimental and empirical evidence show that bidding behavior is more competitive than predicted by standard auction theory, which assumes that bidders only care about maximizing absolute payoffs (e.g. Cox et al., 1985, 1988; Kagel et al., 1987; Kagel and Levin, 1993; Ku et al., 2005). This chapter theoretically explores social comparison concerns as a potential explanation for this observed behavior. That is, we study what happens when bidders anticipate the emotions from the social comparison process and take these into account when formulating their bidding strategies.

The tendency to compare our abilities, opinions or achievements to those of others has both advantages and disadvantages. In an effort to gain accurate self-evaluations, we compare ourselves to those who are worse off than us and/or to those who are better off than us. Whereas comparisons of the first kind result in positive self-evaluations, comparisons of the second kind result in negative self-evaluations. But apart from helping us in evaluating ourselves, social comparison may also drive competitive behavior. In the 1950's, Festinger (1954) laid the foundations of social comparison theory and linked the concept to competitiveness. He argued that by comparing ourselves to others, we have a preference for maximizing relative payoffs and this generates "competitive behavior to protect one's superiority" (Festinger, 1954, p.126).

The economics literature initially assumed that agents care only about maximizing absolute monetary payoffs. Although this view is still dominant in the literature, in recent years economists have worked on issues regarding relative payoffs and interdependent preferences. It is owed to Veblen (1899) and Duesenberry (1949) that social comparison and relative payoffs are considered in economic research. Nowadays, a large body of empirical evidence on the relevance of relative rather than absolute payoffs exists, for example, in the fields of job satisfaction (Clark and Oswald, 1996; Card et al., 2012) and happiness research (Ferrer-i-Carbonell, 2005; Vendrik and Woltjer, 2007). After the rise of experimental economics, which revealed behavior inconsistent with theory, game theorists have increasingly started incorporating interdependent preferences in their models (e.g. Fehr and Schmidt, 1999; Bolton and Ockenfels, 2000; Maccheroni et al., 2012). However, the extent to which interdependent preferences have been modeled in the context of auctions is limited.

The aim of this chapter is to study how social comparison concerns affect bidding behavior in auctions and to relate the predicted behavior to observations from lab and field experiments and online and offline auctions. To study social comparison concerns in isolation, this chapter exclusively looks at sealed bid auctions, i.e., first-price and second-price auctions. The reason for this is that preferences for maximizing relative payoffs in auctions may be the result of social comparison concerns, a personal characteristic exogenous to the auction, but it may also evolve endogenously during the bidding process. In dynamic auctions, such as English and Dutch auctions, the identity of the bidders is often disclosed and bids may be observed by all other bidders. According to Malhotra (2010, p. 140), bidders in dynamic auctions "start out with the goal of making wise decisions and maximizing their own payoff, but as the competition unfolds, their motivation shifts towards 'beating the other side'". This process, known as auction fever, is absent in sealed bid auctions. This makes them excellent environments to study the link between social comparison concerns and competitiveness, thereby excluding confounding factors affecting competitiveness.

To derive the symmetric equilibrium bidding strategies for first-price and second-price auctions when bidders have social comparison concerns, we adopt a model of interdependent preferences. In this model the bidder's utility function consists of two additive components: a monetary and a social component. Monetary utility is a function of a bidder's own payoff; social utility is a function of the difference in payoffs between a bidder and the competing bidders. We assume that bidders derive utility from being better off than others, i.e., they experience pride. Conversely, bidders derive disutility from being worse off than others, i.e., they experience envy. In first instance, we suppose that bidders compare themselves to each of the competing bidders while accounting for the size of the reference group. That is, social utility is normalized by dividing each social comparison by the number of competing bidders. We later show that qualitatively similar results can be obtained when bidders compare themselves either to each of the competing bidders without accounting for the size of the reference group, or only to the potential winner of the auction.

We find that social comparison concerns result in more competitive bidding behavior in both first-price and second-price auctions. The anticipation of envy, or upward comparison concerns, is a necessary condition to generate overbidding. Furthermore, an increase in upward comparison concerns leads to an increase in bids. The anticipation of pride, or downward comparison concerns, has an unexpected effect on bidding behavior. Not only is the sole anticipation of pride not enough to generate overbidding, when combined with envy it even leads to a decrease in bids. Our findings further indicate that the second-price auction generates higher expected revenues than the first-price auction when social comparison concerns are taken into account.

This study adds to the literature analyzing the effects of interdependent preferences on economic decision making. The most general model of interdependent preferences is the one developed by Maccheroni et al. (2012). It starts from the premise that agents do not only derive utility from the outcome of their own decisions, but also from the comparison of their own outcomes to those of others in the reference group. Other important studies in this field are those by Fehr and Schmidt (1999) and Bolton and Ockenfels (2000) on inequity aversion; Linde and Sonnemans (2012), Gamba and Manzoni (2014) and Schwerter (2015) on decision making under uncertainty; Immorlica et al. (2015) on status seeking; and Ghiglino and Goyal (2010) on equilibrium prices, allocations and welfare. All of the studies above presume that agents derive disutility from being worse off than others. However, there is some disagreement about the emotions experienced when being better off than others. Whereas some models posit that being better off than others makes agents feel proud, models building on inequity aversion posit that this makes them feel guilty. This chapter follows the former perspective, but will also discuss the implications on bidding behavior when bidders are inequity averse.

Our study also adds to the literature on overbidding and other trends in auctions. Several adaptations to the standard utility function have been suggested to explain overbidding such as risk aversion, ambiguity aversion, regret aversion, joy of winning, fear of losing, spite and reference-dependent preferences.[1] Especially the concepts joy of winning, fear of losing and spite are similar to social comparison concerns. Joy of winning and fear of losing are the positive and negative emotions caused by winning and losing the auction, respectively (e.g. Roider and Schmitz, 2012). The motivation for these emotions mainly comes from the social competition inherent to auctions. For example, Ockenfels et al. (2006) argue that joy of winning stems from the thrill of competing against others and Fliessbach et al. (2007) suggest that it results from the drive to outperform others. Furthermore, Delgado et al. (2008) find that the emotions experienced when losing are significantly stronger in auctions than in lotteries and van den Bos et al. (2008) find that overbidding disappears when bidders play against computerized opponents instead of human opponents. These findings rule out any explanation for overbidding based on a bidder's own payoffs alone. As a result, we believe that a model based on social comparison concerns better captures the psychological motives behind joy of winning and fear of losing than existing alternatives.

Morgan et al. (2003), Brandt et al. (2007), Sharma and Sandholm (2010) and Nishimura et al. (2011) analyze bidding behavior of spiteful agents in auctions and find that experiencing spite may result in overbidding. The study of Morgan et al. is closest to ours as they model spiteful bidding behavior by introducing a disutility to losing equal to the winner's surplus. In this sense, our model is a generalization of the one by Morgan et al. By incorporating a concern for social comparison, we derive novel predictions on the effects of downward and upward comparison concerns and are additionally able to analyze the effects of considering different referents or reference groups.

The remainder of this chapter is structured as follows. Section 4.2 discusses and compares alternative models predicting overbidding in auctions. Section 4.3 describes the model in detail. Section 4.4 derives the bidding behavior of bidders with social comparison concerns in the first-price auction (Section 4.4.1) and in the second-price auction (Section 4.4.2), and shows the implications of social comparison concerns on the revenue ranking between the auctions (Section 4.4.3). Section 4.5 explores the robustness of

[1] Section 4.2 discusses the literature on overbidding in auctions in further detail.

the model by introducing alternative modeling assumptions (Section 4.5.1) and inequity aversion (Section 4.5.2). Finally, Section 4.6 concludes. All proofs can be found in Appendix C.

4.2 Overbidding in auctions

The standard auction model, which was introduced by Vickrey (1961), assumes that each bidder in an auction only cares about whether or not she wins the good for sale and about the price she pays in case of winning. In this context, it has been shown that in the second-price auction (SPA) each bidder has a weakly dominant strategy of bidding an amount equal to her own private value of the good. In the first-price auction (FPA), there exists a symmetric equilibrium such that each bidder bids the expected highest value among her rivals, conditional on her value being the highest. However, experimental and empirical studies find that bidders bid more competitively than predicted by standard auction theory. This phenomenon is called overbidding and is present in both FPAs and SPAs. Whereas some theories suggest that overbidding is the result of bounded rationality[2] and should disappear as bidders become more experienced,[3] most theories explaining overbidding are, like ours, based on non-standard preferences. In this section, we give an overview of alternative theories and discuss related experimental and empirical studies.

The leading theory explaining overbidding in the FPA refers to risk aversion. Various studies have shown that, if a bidder is risk averse, increasing her bid leads to a utility gain from the increase in the probability of winning the auction that is greater than the cost of paying a higher price (e.g. Riley and Samuelson, 1981; Maskin and Riley, 1984; Cox et al., 1985, 1988). However, risk aversion does not predict overbidding in the SPA. In this case, bidding truthfully remains a weakly dominant strategy. An explanation for overbidding based on risk aversion alone is therefore not sufficient.

A related explanation for overbidding is based on bidders' attitudes towards uncertainty, i.e., the theory of ambiguity aversion (Salo and Weber,

[2]For example, Kagel et al. (1987) argue that overbidding in SPA is the result of the mistaken belief that overbidding will increase the probability of winning at little cost. Crawford and Iriberri (2007) study a model of level-k thinking, which predicts overbidding in FPA (for non-uniform distributions) but not in SPA. In a novel study, Kirchkamp and Reiß (2011) find that both theories based on non-standard preferences and on bounded rationality explain some of the bidding behavior observed in experiments, but also find that most of the bidding behavior is explained by non-standard preferences.

[3]However, Kagel and Levin (1993) and Cooper and Fang (2008) find that overbidding in SPA does not decrease with experience.

1995; Lo, 1998; Chen et al., 2007). The relevance of ambiguity aversion in the FPA stems from the complexity of the bidding process. For any given bid, the probability of winning the FPA depends on the distribution of values of all competing bidders and on their unknown bidding strategies. As a result, bidders may not be able to form a clear understanding of their probability of winning the auction. Salo and Weber argue that ambiguity averse bidders underestimate their chances of winning the FPA and therefore have the tendency to place higher bids. As in the case of risk aversion, bidding one's true value remains a weakly dominant strategy in the SPA when bidders are ambiguity averse.

If bidders anticipate regretting the outcome of the auction, this may lead to overbidding in the FPA but not in the SPA (Engelbrecht-Wiggans, 1989; Engelbrecht-Wiggans and Katok, 2007; Filiz-Ozbay and Ozbay, 2007). Regret in auctions takes two forms: winner regret and loser regret. Bidders may regret winning the auction if they could have generated a higher payoff by bidding less while maintaining their winning position, or if they won at an unfavorable price. Losing bidders may experience regret if the winning price is lower than their value, meaning that they forwent a chance of winning the auction at a favorable price. Whereas loser regret predicts overbidding in the FPA, winner regret predicts underbidding. In an experiment which manipulates information feedback, Filiz-Ozbay and Ozbay (2007) find that bidders anticipate loser regret but do not anticipate winner regret. Therefore, regret aversion results in overbidding in the FPA.

Note that modeling regret in auctions is similar to modeling social comparison concerns, namely bidders have reference-based utility in both approaches. Whereas bidders who are regret averse care about differences between realized and potential payoffs, bidders who are concerned with social comparisons care about differences between their own payoff and their competitors' payoffs.

An alternative way of making utility reference-dependent is by assuming that bidders, if they win the auction, compare their payment to some reference point that is either (partially) determined by the reserve price (Rosenkranz and Schmitz, 2007) or equal to the expected price (Ahmad, 2015). This reflects the idea that bidders experience paying less than the reference point as a gain and experience paying more as a loss. Rosenkranz and Schmitz and Ahmad show for both the FPA and the SPA that this leads low value bidders to increase their bids in order to increase the probability of winning and leads high value bidders to lower their bids in order to reduce the disutility from paying more than the reference point. Lange and Ratan (2010) analyze bidding behavior when bidders are loss averse, either in the commodity dimension or in the money dimension.[4] By considering these two dimensions separately, they find that loss aversion has different effects on bidding behavior in commodity (real-world) auctions and experimental auctions. In the laboratory, Lange and Ratan predict overbidding in the FPA and truthful bidding in the SPA.

Two concepts that are intuitively similar to social comparison concerns are joy of winning and fear of losing. These concepts are defined as the positive or negative utility derived from winning or losing the auction, "over and beyond any monetary payoffs" (Cooper and Fang, 2008, p.1580), and their relevance is supported by evidence from neuroeconomic experiments. Astor et al. (2013), for example, study immediate emotions of winning or losing a FPA by measuring psychophysiological reactions (skin conductance response to measure intensity of emotional response and heart rate to measure valence of emotion, i.e., whether an emotion is positively or negatively perceived). They find evidence for both joy of winning and fear (or frustration) of losing. Cox et al. (1988) were the first to introduce a constant joy of winning into standard auction theory. The framework was developed further by many others, for example, Ding et al. (2005), Cooper and Fang (2008), Ertaç et al. (2011) and Cramton et al. (2012).[5] Most recently, Roider and Schmitz (2012) found that joy of winning and fear of losing can explain some of the bidding behavior observed in the lab: Whereas overbidding in the SPA takes place regardless of the values of bidders, in the FPA there is overbidding for large values and underbidding for small values (e.g. Cox et al., 1985, 1988; Kagel et al., 1987; Kagel and Levin, 1993; Cooper and Fang, 2008).

Even though the concepts of joy of winning and fear of losing are similar to downward comparison concerns (pride) and upward comparison concerns (envy), respectively, their effects on bidding behavior are quite different. Roider and Schmitz (2012) predict that bids are increasing in the joy of winning in both the FPA and the SPA. Additionally, bids are increasing in fear of losing in the SPA. In the FPA, however, bids are increasing in fear of losing when values are sufficiently high and decreasing in fear of losing when values are sufficiently low. As will be shown in Section 4.4, this is in stark contrast with our findings, which state that bids are (weakly) decreasing in pride and increasing in envy.

In terms of interdependent preferences, two approaches are worth mentioning: impulse balance theory and spite. Ockenfels and Selten (2005)

[4] Loss aversion in the commodity dimension refers to the disutility derived from not winning the good. Likewise, loss aversion in the money dimension refers to the disutility derived from losing money.

[5] See Astor et al. (2013) for an extensive overview of the literature on joy of winning and fear of losing in auctions.

report that providing feedback on losing bids in repeated FPAs decreases bids. They explain this using the concept of weighted impulse balance equilibrium, which reflects a concern for social comparison. However, their model is unable to explain the initial overbidding observed before feedback is provided.

Theories on bidding behavior of spiteful bidders are probably closest to our theory of social comparison concerns. Morgan et al. (2003) were the first to analyse spite in auctions and modeled this by introducing an additional disutility to losing equal to the winners surplus. This leads bidders to raise their bids in both FPAs and SPAs, in order to reduce the probability that a competing bidder wins or to raise the price this bidder pays in case she does win. Brandt et al. (2007) also analyse bidding behavior of spiteful agents. In contrast to Morgan et al., in their model bidders maximize a convex combination of their own payoff and the winning bidder's payoff. By doing so, Brandt et al. are able to study the extremes of completely self-interested or malicious bidders. Finally, Sharma and Sandholm (2010) and Nishimura et al. (2011) extend the models of spiteful bidding by analysing asymmetric spite and reciprocity, respectively. Our model of social comparison concerns can be interpreted as a generalization of the spite model by Morgan et al. (2003). This way, our study extends the literature on spiteful bidding by introducing downward comparison concerns next to upward comparison concerns.

While many different theories explaining bidding behavior observed in auctions exist, there is hardly any consensus on which of these theories best explains experimental and empirical evidence. Cooper and Fang (2008), for example, experimentally study overbidding in SPAs where bidders may receive noisy signals about competitors' values. They report that both joy of winning and spite explain bidding behavior to some extent. In an experiment that also varies information about competitors' values, however, Andreoni et al. (2007) find that the pattern of overbidding is consistent with risk aversion in the FPA and spite in the SPA, but not with joy of winning. Goeree and Offerman (2003) conduct an experiment involving SPAs, where values are either private though uncertain or common. Whereas their findings support loss or risk aversion, there is no evidence for joy of winning.

In a study using functional magnetic resonance imaging, Delgado et al. (2008) vary the type of social competition to examine neural correlates of winning and losing. They find that winning results in increased brain activity in the striatum, regardless of whether subjects participate in the FPA or in the lottery game. Losing, on the other hand, results in decreased brain activity in the striatum if subjects participate in the FPA, but it does not affect brain activity if subjects participate in the lottery game. Moreover, Delgado et al. observe a correlation between a subject's tendency to overbid and the amount to which brain activity in the striatum decreased when losing the FPA. They observe no such correlation for winning the FPA. Finally, the authors demonstrate that framing an auction to emphasize loss increases overbidding. This suggests that overbidding cannot be explained by joy of winning, but that it is rather driven by fear of losing the social competition. In a similar setting, van den Bos et al. (2013a) show that the extent to which bidders overbid is related to their desire for social status, which is measured by emphasis placed on social identity and bidders' testosterone levels. Section 4.4 will show that our predictions are in line with the findings of Delgado et al. and van den Bos et al.

4.3 Model

In this section, we define the utility function of agents with social comparison concerns (Section 4.3.1) and introduce the framework of the auction setting (Section 4.3.2).

4.3.1 Social comparison concerns

An agent who has social comparison concerns cares about her own payoff as well as the difference in payoffs between her and her competitors. In accordance with most of the literature on interdependent preferences, an agent's utility function is modeled as consisting of two additive components: a monetary and a social component.[6] Whereas monetary utility solely depends on the agent's own payoff, social utility also depends on the payoffs of competing agents.

Notice that when an agent compares her payoff to those of others, she may evaluate her payoff both as desirable and undesirable, depending on who or what she compares herself to. Therefore, to capture the notion of comparison in the social utility term, it is necessary to first identify the referent or reference group.

Despite the efforts of social psychologists to identify potential referents and to examine the outcomes of referent selection, we are not aware of the existence of a decisive framework on referent choice. The psychological literature has instead found that agents seem to select different referents for different situations and motivations (Wood, 1989). Festinger (1954) argues that agents prefer to compare themselves to similar others, where similarity refers to performance as well as characteristics. Other research suggests

[6] See, for example, Fehr and Schmidt (1999), Maccheroni et al. (2012), Ghiglino and Goyal (2010), Immorlica et al. (2015) and Gamba and Manzoni (2014).

that agents prefer to compare themselves to superior others (e.g. Wheeler, 1966) or, conversely, to inferior others (e.g. Wills, 1981). Garcia et al. (2013) additionally mention relevance, relationship closeness and personal history as factors that determine referent choice.

The economics literature focuses less on analyzing referent selection and often simply assumes that the reference group consists of all other participants in the game. Whereas this is a justified assumption in the set-up of an economic experiment with a limited amount of competitors (e.g. Fehr and Schmidt, 1999), it might be problematic in the complex set-up of a large society. Therefore, Ghiglino and Goyal (2010) and Immorlica et al. (2015) suggest that social comparison takes place locally. They study how social comparisons in social networks influence economic decision making, such as prices, allocations and welfare or status seeking. Ghiglino and Goyal also point out that most economic models assume that agents correct for the size of the reference group when comparing their payoffs to those of others, thereby effectively caring about the average payoffs of the reference group. This assumption is in line with the finding of Garcia and Tor (2009), who state that social comparison concerns are decreasing in the number of competitors.[7] While these findings point at the importance of correcting for the size of the reference group, we think it is also possible that agents do not correct for the size of the reference group or compare their payoffs to the aggregate payoffs of the reference group. For example, it seems plausible that an agent feels worse off if multiple others have higher payoffs than her, than if one other has a higher payoff than her.

Summing up, there are two distinct approaches to modeling social utility. Either an agent compares herself to everyone in some reference group, where she may take into account the size of the reference group, or she compares herself only to a single representative agent or payoff. In the first case, social utility can be modeled as a summation of the differences in payoffs with all competing agents. In the second case, social utility can be represented by deviations to some social reference point. In the remainder of the chapter we assume that agents compare their payoffs to the payoffs of all other competing agents, while correcting for the total number of competing agents. In Section 4.5, we show that not correcting for the total number of competing agents or modeling social utility as comparisons to a single representative agent leads to qualitatively similar results.

[7] Garcia and Tor (2009) present five studies on the N-effect: the finding that increasing the number of competitors can decrease competitive behavior, the motivation to compete and social comparison. In these studies, social comparison concerns were assessed by asking to what extent subjects would be inclined to compare themselves to (one of) the other subjects.

Suppose that each agent compares her payoff (m_i) to the payoffs of all other $N-1$ agents (m_j, where $j = 1, 2, ..., N-1$). Agent i's preferences are then described by

$$U_i = u(m_i) + \frac{\varepsilon}{N-1}\sum_{j=1}^{N-1}\max\{G(m_i - m_j), 0\} + \frac{\gamma}{N-1}\sum_{j=1}^{N-1}\min\{G(m_i - m_j), 0\} \qquad (4.1)$$

where monetary utility is represented by $u(m_i)$ and social utility by $G(m_i - m_j)$. To capture the notion that utility is increasing in both absolute and relative payoffs, suppose that $u(0) = G(0) = 0$, $u' > 0$, and $G' > 0$.

Some remarks are in order here. First, our model allows for different weights for comparisons to agents with lower payoffs (ε) and to agents with higher payoffs (γ). Comparisons of the former kind are referred to as downward comparisons and may lead to pride. Comparisons of the latter kind are referred to as upward comparisons and may lead to envy or spite.[8] We assume that ε and γ are nonnegative but do not place an upper bound on the parameter range. Kahneman and Tversky (1979) introduced the idea that agents evaluate gains and losses differently. Since then, a vast amount of literature has demonstrated that agents care more about losses than gains in the monetary domain (e.g. Tversky and Kahneman, 1991). Using a combination of neuroeconomic and behavioral economic techniques, Delgado et al. (2008) confirm the existence of loss aversion in the social domain. In a similar study, however, Bault et al. (2008) find the exact opposite: social gains are given more weight than social losses. This is in line with the study of Astor et al. (2013), who measure psychophysiological reactions to find that winning is experienced more intensely than losing. As a result of these contradictory findings, we choose not to make any further restrictions on the relationship between ε and γ.

Second, we assume that agents are symmetric, meaning that all agents have the same coefficients ε and γ. Although it is certainly interesting to consider agents with heterogeneous social comparison concerns, or give different weights to comparisons to different competing agents, we leave this for future work. Third, in order to correct for the size of the reference group, social utility is normalized by dividing each social comparison by $N-1$. This reflects the idea that agents care about the average payoffs of

[8] Note that $G(m_i - m_j)$, when different from 0, is positive for downward comparisons, such that agents derive utility from being better off than others. Likewise, $G(m_i - m_j)$ is negative for upward comparisons, such that agents derive disutility from being worse off than others.

the competitors and that social comparison concerns can be decreasing in the number of competitors. Finally, for simplicity, in the remainder of the chapter we assume that the utility function is linear both in monetary (u) and social utility (G).

4.3.2 Auction setting

Now consider a monopolistic seller offering a single unit of a homogeneous good to $N \geq 2$ symmetric bidders in a sealed bid auction. The auction format may be a FPA or SPA. Regardless of the auction format, if bidder i wins the auction and pays p_i, her payoff equals $v_i - p_i$. Here $v_i \in [0, 1]$ is a bidder's valuation of the good, which is independently and identically distributed according to the distribution function $F(v)$, with strictly positive density $f(v)$. If bidder i loses the auction her payoff is zero.

Notice that for social comparison concerns to have any effect on bidding behavior, each bidder needs to be able to calculate the expected payoffs of all competing bidders. This requires that each bidder knows her own value v_i and the distribution of values $F(v)$. With this information she can calculate the expected values of all competing bidders and, assuming that bidders use symmetric and strictly increasing bidding strategies, the expected payments of these bidders. Further note that, because in auctions the "winner takes it all", only the winning bidder compares her payoffs to those of $N - 1$ losing bidders; the losing bidders compare their payoffs to those of a single winner.[9]

4.4 Bidding behavior

In Sections 4.4.1 and 4.4.2, the symmetric Bayesian Nash equilibrium bidding strategies for the first-price and second-price auction are derived. Section 4.4.3 compares the expected revenues of the two auctions. The notation that is used throughout the chapter is largely based on the one used by Brandt et al. (2007). Let us point out that $v_{(n)}$ denotes the nth highest private value.[10]

[9] This does not imply that downward comparisons count more than upward comparisons; one may vary ε and γ in any way desired.

[10] Our terminology and notation follows the one used in auction theory and not the one used in probability theory. Hence, the highest value is denoted by $v_{(1)}$ and the second highest value by $v_{(2)}$. The lowest of $N - 1$ values is denoted by $v_{(N-1)}$.

4.4.1 First-price auction

In the FPA, only the winning bidder receives a nonzero payoff equal to her value minus her own bid. Hence, assuming that bidders $j \neq i$ follow the symmetric bidding strategy $b(v_j)$, if bidder $k \neq i$ wins the auction, her payoff is $v_k - b(v_k)$. As we focus on an independent private values setting, each bidder knows her own value but does not know the values of the $N-1$ competing bidders. However, she does have probabilistic beliefs about these values. Assuming a strictly increasing bidding strategy, bidder k can only win the auction if she has the highest value among $N-1$ competing bidders. Hence, k's expected payoff conditional on i not winning the auction equals $v_k - b(v_k) = E[v_{(1)}|\neg W_i] - E[b(v_{(1)})|\neg W_i]$, where W_i denotes the event that i wins the auction.

Following the model introduced in Section 4.3, the utility of bidder i, who has value v_i and bids $b_i(v_i)$, in the FPA is given by

$$U_i = \begin{cases} (v_i - b_i(v_i)) + \frac{\varepsilon}{N-1} \sum\limits_{j=1}^{N-1} \left((v_i - b_i(v_i)) - 0\right), & \text{if } i \text{ wins} \\ \\ 0 + \frac{\gamma}{N-1} \left(0 - (E[v_{(1)}|\neg W_i] - E[b(v_{(1)})|\neg W_i])\right) & \\ \quad + \frac{\gamma}{N-1} \sum\limits_{j=2}^{N-1} (0 - 0), & \text{if } k \neq i \text{ wins} \end{cases} \tag{4.2}$$

If bidders are not concerned with social comparisons, such that $\varepsilon = \gamma = 0$, the social utility components in (4.2) drop out and we are left with the utility function studied by standard auction theory, which results in the Risk Neutral Nash Equilibrium (RNNE). In this case, theory predicts a symmetric equilibrium in which each bidder bids an amount equal to the expectation of the highest of $N-1$ values below her own value v. We find that bidders who have social comparison concerns shade their bids in a similar way, but at the same time tend to bid more than predicted in the RNNE.

Proposition 4.1 *The symmetric equilibrium for bidders with social comparison concerns in first-price auctions is given by the bidding strategy*

$$b^{FPA}(v) = v - \int_0^v \left(\frac{F(t)}{F(v)}\right)^{\frac{(1+\varepsilon)(N-1)+\gamma}{1+\varepsilon}} dt \tag{4.3}$$

The proof of Proposition 4.1 can be found in Appendix C. Notice that the bidding strategy is strictly increasing in the value, which satisfies our initial assumption.

Following Brandt et al. (2007), the bidding strategy can be reformulated as a conditional expectation $b^{FPA}(v) = E[X|X < v]$, where X is drawn from $F(x)^{((1+\varepsilon)(N-1)+\gamma)/(1+\varepsilon)}$. This implies that in equilibrium it is as if each bidder bids an amount equal to the expectation of the highest of $((1+\varepsilon)(N-1)+\gamma)\,/\,(1+\varepsilon)$ values below her own value v. From this, one can easily see that for $\gamma = 0$ the bidding strategy is equal to the RNNE bidding strategy. However, for any $\gamma > 0$ overbidding occurs. An explanation for this lies in the amount of bid shading, which is given by the second term of the right-hand side (RHS) of (4.3). As $\frac{F(t)}{F(v)} \leq 1$ for any $0 \leq t \leq v$, it follows that as the exponent $((1+\varepsilon)(N-1)+\gamma)\,/\,(1+\varepsilon)$ increases, the amount of bid shading decreases and the bid increases. Notice that the exponent is increasing in γ and in N. Surprisingly, the exponent is decreasing in ε, but only for positive γ. This implies the following.

Corollary 4.1 *In first-price auctions with $N \geq 2$ bidders who have social comparison concerns, the following holds:*

- *If $\gamma = 0$, for any $\varepsilon \geq 0$ the symmetric equilibrium is given by the RNNE bidding strategy.*
- *If $\gamma > 0$, the following results hold:*
  - *(i) Overbidding occurs.*
  - *(ii) The bids and the amount of overbidding are increasing in upward comparison concerns, γ.*
  - *(iii) The bids and the amount of overbidding are decreasing in downward comparison concerns, ε.*
  - *(iv) The bids are increasing in N and the amount of overbidding is decreasing in N.*

The proof of Corollary 4.1 can be found in Appendix C.

Corollary 4.1 implies that upward comparison concerns (envy) are a necessary condition for overbidding and that downward comparison concerns (pride) impede the effect that upward comparison concerns have. The effect of upward comparison concerns is in line with the results of Morgan et al. (2003): the more spiteful or envious a bidder is, the more she will overbid. We further find that as the concern for upward comparison increases, the amount of bid shading approaches zero and bids converge to a bidder's own value v. The effect of downward comparison concerns, however, is surprising. First, the sole anticipation of pride is not enough to generate overbidding. Second, if a bidder is both proud and envious, then the more proud a bidder is, the less she overbids.

The intuition for these findings is best understood in the two-bidder scenario.[11] Suppose that both bidders initially intend to bid according to the RNNE bidding strategy, but that bidder 1 now considers raising her bid. This increases the probability that she wins the auction, but also increases the price she has to pay in case she wins. These effects enter both in the monetary and social utility term, where the former receives a weight of 1 and the latter receives a weight of ε. At the same time, raising her bid decreases the probability that bidder 2 wins the auction, thereby decreasing the expected payoff of bidder 2. This effect enters in the social utility term, which now receives a weight of γ. Hence, bidder 1's marginal benefits from raising her bid are given by $1+\varepsilon+\gamma$. Her marginal costs are given by $1+\varepsilon$. This implies that if bidder 1 is solely concerned with upward comparisons, the marginal benefits are greater than the marginal costs. Therefore, an envious bidder finds it fruitful to raise her bid. If bidder 1 is only concerned with downward comparisons, however, the marginal benefits from raising her bid exactly offset the marginal costs. Finally, if she is concerned with both upward and downward comparisons, an increase in downward comparison concerns leads to a greater relative increase in marginal costs than in marginal benefits. In other words, increasing downward comparison concerns changes the ratio of marginal benefits to marginal costs in favor of marginal costs, thereby leading to a decrease in overbidding.

Corollary 4.1 further implies that, if bidders have social comparison concerns, bids are increasing in the number of bidders. Moreover, as the amount of bidders increases, the amount of bid shading approaches zero and bids converge to a bidder's own value v. The exact same result holds for the RNNE bidding strategy. Therefore, it follows that the amount of overbidding decreases in the number of bidders. This is in line with the results obtained by Ku et al. (2005), Garcia and Tor (2009) and Malhotra (2010), who find that competitive behavior is decreasing in the number of competitors and that this is mediated by social comparison concerns.

An alternative way of formulating (4.3) is as a function of a parameter z, where $z = \frac{\gamma}{(1+\varepsilon)(N-1)}$. In this case, the equilibrium bidding strategy can be written as

$$b^{FPA}(v,z) = v - \int_0^v \left(\frac{F(t)}{F(v)}\right)^{(1+z)(N-1)} dt \qquad (4.4)$$

Note that $b^{FPA}(v,z)$ is equal to the RNNE bidding strategy if $z=0$, and that $b^{FPA}(v,z)$ is increasing in v for any $z \geq 0$. As $b^{FPA}(0,z) = 0$ and

[11] Note that in the two-bidder scenario, the symmetric equilibrium bidding strategy is given by $b^{FPA}(v) = v - \int_0^v \left(\frac{F(t)}{F(v)}\right)^{\frac{1+\varepsilon+\gamma}{1+\varepsilon}} dt$.

$b^{FPA}(v, z)$ is continuous and increasing in z (see Appendix C), this suggests that the amount of overbidding is increasing in v. This can readily be illustrated for the case of uniformly distributed values, i.e., $F(v) = v$.[12] The equilibrium bidding strategy in the FPA is then given by

$$b^{FPA}(v, z) = \frac{(1 + z)(N - 1)}{(1 + z)(N - 1) + 1} v$$

The amount of overbidding is given by

$$b^{FPA}(v, z) - b^{FPA}(v, 0) = \left[(z(N - 1))/(zN(N - 1) + N^2)\right] v$$

Thus, it immediately follows that the amount of overbidding is increasing in v when values are uniformly distributed.

4.4.2 Second-price auction

In the SPA, if bidder i wins the auction, she pays an amount equal to the bid of the second highest bidder. Again assuming bidders $j \neq i$ follow the strictly increasing and symmetric bidding strategy $b(v_j)$, bidder i's payment is given by $E[b(v_{(1)})|W_i]$. If bidder $k \neq i$ wins the auction, bidder i receives a zero payoff and bidder k receives a payoff equal to her value minus the bid of the second highest bidder. Therefore, we must distinguish between two possible scenarios. First, if bidder i submits the second highest bid, k's payment is $b_i(v_i)$. Second, if the second highest bid is greater than $b_i(v_i)$, k's payment is given by the expected bid of the bidder with the second highest value. Hence, if bidder k wins the auction, her expected payment is given by

$$\begin{aligned} B(v_k) = &Pr\left(b_i(v_i) < b(v_{(1)}) \wedge b_i(v_i) > b(v_{(2)})\right) b_i(v_i) \\ &+ Pr\left(b_i(v_i) < b(v_{(2)})\right) E[b(v_{(2)})|b_i(v_i) < b(v_{(2)})] \end{aligned}$$

Hence, bidder i's utility function in the SPA is given by

$$U_i = \begin{cases} \left(v_i - E[b(v_{(1)})|W_i]\right) \\ \quad + \frac{\varepsilon}{N-1} \sum_{j=1}^{N-1} \left(\left(v_i - E[b(v_{(1)})|W_i]\right) - 0\right), & \text{if } i \text{ wins} \\ \\ 0 + \frac{\gamma}{N-1} \left(0 - (E[v_{(1)}|\neg W_i] - B(v_k))\right) \\ \quad + \frac{\gamma}{N-1} \sum_{j=2}^{N-1} (0 - 0), & \text{if } k \neq i \text{ wins} \end{cases} \tag{4.5}$$

[12] Most of the experimental literature on auctions assumes that values are uniformly distributed (Kagel, 1995).

As in the FPA, if bidders are not concerned with social comparisons, meaning that $\varepsilon = \gamma = 0$, U_i equals the utility function studied in standard auction theory. This predicts that bidders have a weakly dominant strategy to bid truthfully, which means that they bid an amount equal to their own value v. However, a vast amount of experimental literature finds that bidders in the SPA place bids above the dominant strategy bids (e.g. Kagel et al., 1987; Kagel and Levin, 1993; Harstad, 2000). We find that social comparison concerns may explain such behavior.

Proposition 4.2 *The symmetric equilibrium for bidders with social comparison concerns in second-price auctions is given by the bidding strategy*

$$b^{SPA}(v) = v + \int_v^1 \left(\frac{1 - F(t)}{1 - F(v)} \right)^{\frac{(1+\varepsilon)(N-1)+\gamma}{\gamma}} dt \tag{4.6}$$

The proof of Proposition 4.2 can be found in Appendix C. The bidding strategy is strictly increasing in the bidder's value, which means that our initial assumption is satisfied.

From Proposition 4.2 it can immediately be seen that bidders with social comparison concerns overbid in SPAs.[13] The amount of overbidding is given by the second term on the RHS of (4.6). As $\frac{1-F(t)}{1-F(v)} \leq 1$ for any $v \leq t \leq 1$, it follows that as the exponent $((1+\varepsilon)(N-1)+\gamma)/\gamma$ decreases, the amount of overbidding increases. Notice that the exponent is decreasing in γ and that in the limit, as γ decreases to 0, the amount of overbidding decreases to zero.[14] The exponent is increasing in N and in ε, but only for positive γ. This implies the following.

[13] Similar to Proposition 4.1, the bidding strategy in Proposition 4.2 can be reformulated as a conditional expectation $b^{SPA}(v) = E[X|X > v]$, where X is drawn from $1 - [1 - F(x)]^{((1+\varepsilon)(N-1)+\gamma)/\gamma}$. This implies that in equilibrium it is as if each bidder bids an amount equal to the expectation of the lowest of $((1+\varepsilon)(N-1)+\gamma)/\gamma$ values above her own value v.

[14] In the proof of Proposition 4.2 in Appendix C we formally show that for $\gamma = 0$ the symmetric equilibrium is given by the RNNE bidding strategy $b^{SPA}(v) = v$.

Corollary 4.2 *In second-price auctions with $N \geq 2$ bidders who have social comparison concerns, the following holds:*

- *If $\gamma = 0$, for any $\varepsilon \geq 0$ the symmetric equilibrium is given by the RNNE bidding strategy.*
- *If $\gamma > 0$, the following results hold:*
  - *(i) Overbidding occurs.*
  - *(ii) The bids and the amount of overbidding are increasing in upward comparison concerns, γ.*
  - *(iii) The bids and the amount of overbidding are decreasing in downward comparison concerns, ε.*
  - *(iv) The bids and the amount of overbidding are decreasing in N.*

The proof of Corollary 4.2 can be found in Appendix C.

Corollary 4.2 confirms that upward comparison concerns (envy) and downward comparison concerns (pride) have the same effect on bidding behavior in the SPA as in the FPA. That is, upward comparison concerns are a necessary condition for overbidding and the more envious a bidder is, the higher she bids. This is in line with the model of spiteful bidding by Morgan et al. (2003). Downward comparison concerns only affect bidding behavior whenever bidders are also concerned with upward comparisons. In this case, the more proud a bidder is, the less she overbids.

Again, these results are best explained in an auction with two bidders, where we assume that bidder 2 follows the weakly dominant strategy of bidding her own value.[15] Now consider what happens if bidder 1 were to raise her bid. First, this would lead to a marginal benefit from the increase in the probability of winning the auction. As this enters both in the monetary and the social utility term, this marginal benefit receives a weight of $1+\varepsilon$. Second, it would also lead to a marginal cost of winning at a price in excess of her value. This marginal cost again receives a weight of $1+\varepsilon$. Hence, if a bidder only cares about downward comparison concerns, the marginal benefits cancel out the marginal costs and she continues to bid truthfully. If bidder 1 is also concerned with upward comparisons, however, there exists an additional marginal benefit. Indeed, if bidder 1 raises her bid, this decreases the probability that bidder 2 wins the auction. As bidder 2 bids truthfully, however, this does not decrease her expected payoff and therefore does not result in a marginal benefit for bidder 1. Meanwhile, if bidder 1 raises her bid, this also increases the price bidder 2 has to pay

[15] Note that in the two-bidder scenario, the symmetric equilibrium bidding strategy is given by $b^{SPA}(v) = v + \int_v^1 \left(\frac{1-F(t)}{1-F(v)}\right)^{\frac{1+\varepsilon+\gamma}{\gamma}} dt$.

in case she wins the auction. This marginal benefit receives a weight of γ. Summing up, bidder 1's marginal benefits from raising her bid are given by $1 + \varepsilon + \gamma$; her marginal costs are given by $1 + \varepsilon$. As a result, if a bidder cares about upward comparisons, she indeed overbids. An increase in the concern for downward comparisons leads to a larger relative increase in marginal costs than in marginal benefits, thereby decreasing the amount of overbidding.

Unlike in the RNNE bidding strategy and in bidding strategies predicted by alternative theories (see Section 4.2 for an overview), the bidding strategy in the SPA for bidders with social comparison concerns depends on the number of bidders participating in the auction. Even more surprising is the finding that bids are decreasing in the number of bidders. More specifically, as the amount of bidders increases, bids will converge to the well-known bidding strategy of bidding one's own value. It therefore follows that the amount of overbidding is decreasing in the number of bidders as well. This finding is in line with the literature on social comparisons and competitive behavior (Ku et al., 2005; Garcia and Tor, 2009; Malhotra, 2010). To the best of our knowledge, our model is the only one that predicts such a relationship and therefore this prediction could nicely serve to formulate a hypothesis to distinguish our model from alternative models.

Like in the FPA, we can formulate (4.6) as a function of a parameter z, where $z = \frac{\gamma}{(1+\varepsilon)(N-1)}$. In this case, the equilibrium bidding strategy can be written as

$$b^{SPA}(v, z) = v + \int_v^1 \left(\frac{1 - F(t)}{1 - F(v)} \right)^{\frac{1+z}{z}} dt \tag{4.7}$$

Note that $b^{SPA}(v, z) \to 0$ as $z \to 0$. Further note that $b^{SPA}(1, z) = 1$ and $b^{SPA}(v, z)$ is increasing in v for any $z \geq 0$. As $b^{SPA}(v, z)$ is continuous and increasing in z (see Appendix C), this suggests that the amount of overbidding is decreasing in v. This can readily be illustrated for the case of uniformly distributed values, i.e., $F(v) = v$. The bidding strategy is then given by

$$b^{SPA}(v, z) = v + \frac{z}{1 + 2z}(1 - v)$$

The amount of overbidding in the SPA is then given by $[z/(1 + 2z)]\,(1 - v)$, which is decreasing in v.

4.4.3 Revenue comparison

Sections 4.4.1 and 4.4.2 described the symmetric equilibrium bidding strategies for the FPA and the SPA when bidders have social comparison concerns. From standard auction theory, we know that the auctions' expected revenues are given by the following expressions.

$$R^{FPA} = \int_0^1 b^{FPA}(v)NF(v)^{(N-1)}f(v)dv$$

$$R^{SPA} = \int_0^1 b^{SPA}(v)N(N-1)F(v)^{(N-2)}f(v)\left[1-F(v)\right]dv$$

If $b^{FPA}(v)$ and $b^{SPA}(v)$ are formulated in terms of z (see (4.4) and (4.7), respectively), then for both auctions, the bidding strategy is increasing in z (see Appendix C). As a result, the expected revenue for both auctions is also increasing in z. This means that the expected revenues are strictly increasing in upward comparison concerns (γ) and weakly decreasing in downward comparison concerns (ε). From the revenue equivalence theorem (e.g. Vickrey, 1961; Myerson, 1981), we know that the expected revenue in the FPA and the SPA is equal when bidders are not concerned with social comparisons, i.e., $z = 0$. By reformulating the bidding strategies in terms of z, we can borrow the result from Morgan et al. (2003) to establish a revenue ranking between the FPA and the SPA when bidders are concerned with social comparisons, i.e., $z > 0$. We state the result without proof, for which we refer to Morgan et al.

Proposition 4.3 (Morgan et al., 2003) *For any* $0 < z \leq 1$ *and* $N \geq 2$ *bidders, the second-price auction yields more expected revenue than the first-price auction.*

Proposition 4.3 implies that the SPA only yields more expected revenue than the FPA when bidders are concerned with upward comparisons. If the number of bidders increases to infinity, or if the concern for downward comparisons increases to infinity, z goes to zero and revenue equivalence is restored. Notice that Proposition 4.3 only provides a revenue comparison for any $z \leq 1$, which requires that $\gamma \leq (1+\varepsilon)(N-1)$.

In Section 4.2 we pointed out that if bidders are spiteful, the expected revenue from the SPA is greater than that of the FPA. Conversely, if bidders are averse to risk, ambiguity, or regret, the revenue ranking is reversed: the expected revenue from the FPA is greater than that of the SPA. If bidders have reference-based utility or experience joy of winning and fear of losing, the auctions are revenue equivalent. Proposition 4.3 can therefore nicely serve as a way to distinguish models based on interdependent preferences from alternative models.

4.5 A remark on robustness

This section discusses alternative ways of determining the referent in social comparisons (Section 4.5.1) and considers the implications of adjusting the model to reflect inequity aversion (Section 4.5.2).

4.5.1 Alternatives for referent choice

Section 4.3.1 introduced several modeling assumptions for determining the referent: either an agent compares her payoff to the payoffs of all other competing agents, where she corrects for the total number of competing agents or not; or she compares herself to a single representative agent or payoff. For our main analysis, we modeled social comparison concerns by summing the differences in payoffs with all competing agents, where each social comparison to an agent received a weight of $\frac{1}{N-1}$. In this section, however, we show that qualitatively similar results are obtained when alternative assumptions for referent choice are used.

Suppose that each agent compares her payoff to the payoffs of all other competing agents without correcting for the total number of competitors. This would only lead to a slight modification of utility function (4.1), as agents now no longer divide each social comparison by $N-1$. As a result, the bidding strategy for the FPA is given by (4.4) and that for the SPA is given by (4.7), where z is now equal to $\gamma/(1+\varepsilon(N-1))$. This means that most of the findings in Corollaries 4.1 and 4.2 also hold for this choice of referent. Bids in both auctions remain increasing in upward comparison concerns and (weakly) decreasing in downward comparison concerns. Whereas in the FPA bids are still increasing in the number of bidders, the amount of overbidding may no longer be decreasing in the number of bidders. In the limit, however, the amount of overbidding decreases to zero, as the bidding strategies for bidders with and without social comparison concerns both converge to v as the number of bidders increases to ∞. As z remains decreasing in N, bids and the amount of overbidding are decreasing in the number of bidders in the SPA. As a result, this finding can still be used to distinguish our model of social comparison concerns from alternative models.

Alternatively, should agent i compare her payoff to that of a representative competing agent, this is modeled as negative or positive deviations from a state-dependent reference point s. Her preferences are then described by

$$U_i = u(m_i) + \varepsilon \max\{G(m_i - s), 0\} + \gamma \min\{G(m_i - s), 0\}$$

Again, assume that $u(m_i)$ represents monetary utility, $G(m_i - s)$ represents social utility, $u(0) = G(0) = 0$, $u' > 0$, and $G' > 0$, and ε and γ represent the concern for downward and upward comparisons, respectively.

Gamba and Manzoni (2014) utilize a similar utility function and mention that reasonable assumptions for the determination of s are the average of the payoffs of other agents, their median, their minimum, or their maximum. Modeling s as the average will produce the same results as the utility function in Section 4.3.1.[16] We interpret the social reference point, s, as being determined by the payoff of a representative agent among the $N-1$ competing agents (m_j, where $j = 1, 2, ..., N-1$). For example, an agent may compare her payoff to that of the best competing agent, which in auctions may be interpreted as the competitor with the highest value. Alternatively, s could be equal to the payoff of any other competing agent, including the competitor with the median or minimum value among the competitors. Notice that s may be state dependent, as the payoff of any agent may vary across different states of the world.

Let us first consider how assuming that a bidder compares her payoff to that of a representative competing bidder affects her utility in the FPA. If bidder i wins the auction, all competing bidders receive a zero payoff. Therefore, the social reference point will be zero, i.e., $s = 0$. If bidder $k \neq i$ wins the auction, the value of the social reference point depends on the choice of the referent. In case bidder i compares her payoff to that of the winning bidder k, the social reference point is given by $s = v_k - b(v_k)$. In case bidder i compares her payoff to that of bidder $j \neq k$, the social reference point is again equal to zero. Bidder i's utility when she compares her payoff to that of the winning bidder k is defined by (4.8); her utility when she compares her payoff to bidder $j \neq k$ is defined by (4.9).

$$U_i = \begin{cases} (v_i - b_i(v_i)) + \varepsilon\left((v_i - b_i(v_i)) - 0\right), & \text{if } i \text{ wins} \\ 0 + \gamma\left(0 - (E[v_{(1)}|\neg W_i] - E[b(v_{(1)})|\neg W_i])\right), & \text{if } k \neq i \text{ wins} \end{cases} \tag{4.8}$$

$$U_i = \begin{cases} (v_i - b_i(v_i)) + \varepsilon\left((v_i - b_i(v_i)) - 0\right), & \text{if } i \text{ wins} \\ 0 + \gamma\left(0 - 0\right), & \text{if } k \neq i \text{ wins} \end{cases} \tag{4.9}$$

We make a similar distinction for the SPA, where bidder i either compares her payoff to that of the winning bidder k (see (4.10)) or to that of any other bidder $j \neq k$ (see (4.11)).

$$U_i = \begin{cases} \left(v_i - E[b(v_{(1)})|W_i]\right) + \varepsilon\left(\left(v_i - E[b(v_{(1)})|W_i]\right) - 0\right), & \text{if } i \text{ wins} \\ 0 + \gamma\left(0 - (E[v_{(1)}|\neg W_i] - B(v_k))\right), & \text{if } k \neq i \text{ wins} \end{cases} \tag{4.10}$$

[16]Note that this follows only because we assume that the social utility G is a linear function. Assuming a nonlinear G may lead to different results.

$$U_i = \begin{cases} \left(v_i - E[b(v_{(1)})|W_i]\right) + \varepsilon\left(\left(v_i - E[b(v_{(1)})|W_i]\right) - 0\right), & \text{if } i \text{ wins} \\ 0 + \gamma(0-0), & \text{if } k \neq i \text{ wins} \end{cases} \tag{4.11}$$

We find that, if the social reference point s is determined by the payoff of the potential winner k, such that utility is defined by (4.8) in the FPA and (4.10) in the SPA, the symmetric equilibria are given by the bidding strategies in (4.4) and (4.7), respectively, where $z = (1+\varepsilon+\gamma)/(1+\varepsilon)$. This implies that bids are again increasing in upward comparison concerns and (weakly) decreasing in downward comparison concerns. However, it also implies that bids and the amount of overbidding in the SPA no longer depend on the number of bidders in the auction. While bids in the FPA remain increasing in the number of bidders, we cannot be certain that the amount of overbidding is decreasing in N. However, like for the RNNE bidding strategy, as the amount of bidders grows to ∞, bids in the limit converge to a bidder's own value v. As a result, the amount of overbidding decreases to zero as the amount of bidders grows.

To the contrary, if the social reference point s is determined by the payoff of any other bidder $j \neq k$, such that utility is defined by (4.9) in the FPA and (4.11) in the SPA, then the symmetric equilibria are given by the RNNE bidding strategies or, alternatively, by (4.4) and (4.7), where $z = 0$. This results from the fact that if bidder $k \neq i$ wins the auction, the payoffs of bidder i and bidder $j \neq k$ are equal. As a result, neither upward comparison concerns nor overbidding occur. In their study, Morgan et al. (2003) claim that if a bidder cares about "the surplus of an arbitrary representative from among her rivals, both the overbidding and the revenue ranking for first- and second-price auctions are preserved" (Morgan et al., 2003, p.6). Our results show that the ranking may change depending on the referent choice in the utility function.

4.5.2 Inequity aversion

Our model assumes that agents experience pride when being better off than others ($\varepsilon \geq 0$) and experience envy when being worse off than others ($\gamma \geq 0$). Alternatively, our model can be adjusted to reflect inequity aversion by assuming that agents do not only dislike being worse off than others but also experience guilt when being better off than others, i.e., $\varepsilon \leq 0$. This section explores the implications of taking the perspective of inequity aversion.

Suppose that each agent's preferences are described by utility function (4.1), where $-1 < \varepsilon \leq 0$ and $\gamma \geq 0$, such that it reflects inequity averse preferences as introduced by Fehr and Schmidt (1999). The former assumption ensures that agents feel guilty about being better off than others, but do not feel guilty to such an extent that they are willing to give up their entire monetary payoffs in order to reduce their advantage over the competing agents. In the context of auctions, this can assumption ensures that winning the auction generates a positive payoff. That is, if $\varepsilon \leq -1$, then the utility a bidder derives from winning the auction is canceled out by the disutility derived from being better off than others. If a bidder receives a negative payoff regardless of whether she wins or loses the auction, she will decide not to participate at all. In their model of inequity aversion, Fehr and Schmidt (1999) additionally require that $|\varepsilon| \leq \gamma$. This assumption reflects loss aversion and is not necessary for our purposes.

Accordingly, it can be shown that the symmetric equilibria for the FPA and the SPA when bidders are inequity averse are given by the bidding strategies in Propositions 4.1 and 4.2, respectively. The results in Corollaries 4.1 and 4.2 also remain valid.[17] We also find that as bidders feel more guilty (which is captured by a decrease in ε), the amount of overbidding increases. A model based on inequity aversion therefore predicts more competitive bidding behavior than a model based on social comparison concerns. This seems counter-intuitive, as typically the presence of guilt predicts more equitable and less competitive outcomes (e.g. Fehr and Schmidt, 1999; Bolton and Ockenfels, 2000).

In light of this result, we believe that assuming bidders to derive utility from being better off than others is most plausible in the context of auctions. Even more so in this chapter, as we focus on single-unit auctions, which are by definition winner-takes-all environments. In such explicit competitive environments it seems highly unlikely that agents do not like being better off than others. Additionally, the auctions literature (as discussed in the Section 4.2) repeatedly finds evidence for the existence of joy of winning, and Astor et al. (2013) even find that winning is experienced more intensely as the amount that is won in the auction increases.

4.6 Conclusion

This chapter investigates how bidders who are concerned with social comparisons bid in first-price and second-price auctions. To answer this question, we adopt a model of interdependent preferences, where individuals compare their payoffs to some social referent and may attach different weights to downward and upward comparisons, and apply this to the context of auctions. Our model predicts that social comparison concerned bidders overbid in both first-price and second-price auctions. More specif-

[17] Note that the assumption that $\varepsilon > -1$ is critical for these results to hold (see Appendices 4.1 and 4.2).

ically, we find that upward comparison concerns are a necessary condition to generate overbidding, and that bids increase as bidders give more weight to upward comparisons. Downward comparison concerns do not affect bidding behavior in isolation, but mitigate the effect of upward comparison concerns. Our model additionally predicts that the second-price auction generates higher expected revenues than the first-price auction. These findings are independent of the way referent choice is modeled.

Additionally, we find that if social comparison concerns are modeled as a summation of the difference in payoffs with all competing bidders, where bidders either correct for the total number of competing bidders or not, then the bidding strategy in the second-price auction is decreasing in the number of bidders. To our knowledge, among all models explaining overbidding in auctions, our model is the only one predicting such a relationship. As a result, this prediction could serve to formulate a hypothesis to distinguish our model from alternative models explaining overbidding.

Our findings are consistent with studies identifying the psychological and neurological effects of participating in auctions, and are able to explain the overbidding observed in experiments. Our study is a starting point to incorporate social comparison concerns into auction theory. Future research may consider nonlinear functions of monetary (u) and social utility (G). This allows one to study how incorporating features of prospect theory in both the monetary and the social domain affects bidding behavior. Additionally, it would be interesting to investigate whether our findings are upheld when the model of social comparison concerns is applied to different auctions, such as the all-pay auction. This would strengthen our argument for the importance of social comparison concerns in auctions.

Chapter 5

Conclusion

The studies in this dissertation focus on auctions with competing sellers and behavioral bidders. Chapter 2 theoretically investigates which auctions are selected by competing sellers when they may choose between first-price and second-price auctions and when risk averse bidders endogenously enter one of the auctions. Chapter 3 presents an exploratory experiment analyzing bidders' decisions between participating in an auction with or without a Buy-It-Now option, and buying at a posted price. Chapter 4 theoretically studies how social comparison concerns affect bidding behavior in first-price and second-price auctions. This final chapter summarizes the findings discussed in previous chapters of the dissertation and provides possible directions for further research.

5.1 Discussion of the findings

With the rise of the Internet, the use of auctions has become increasingly prevalent. Nowadays, consumers can buy a myriad of goods by means of online auctions—cars, holidays, clothing, sports items, electronics and even lab equipment are auctioned on the Internet. Economists have studied auctions for several decades, but have traditionally focused on a monopolistic auctioneer selling a single good in a standard auction to a fixed number of fully rational bidders, who are solely concerned with maximizing monetary payoffs. The recent flourishing of online auctions, however, requires that the traditional literature is modified in at least three ways. That is, auction theorists studying online auctions need to consider that bidders may have non-standard preferences and endogenously enter competing auctions, where these auctions may include non-standard ones. The contributions in this dissertation revolve around these three departures from the traditional literature. Chapter 1 provides a general introduction and short theoretical background to the topics dealt with in the dissertation. Chapters 2 to 4 compose the body of the dissertation, and deal with various aspects related to the topics mentioned above. In this section, we summarize the findings of these chapters and additionally discuss some implications for auctioneers.

Competing first-price and second-price auctions

Chapter 2 theoretically studies endogenous entry by risk averse bidders into competing first-price and second-price auctions. The aim of this chapter is to examine how endogenous entry affects the optimal choice of auction format for competing sellers. To this end, we construct an auction selection game consisting of three stages, where multiple units of a homogeneous good are offered simultaneously by competing sellers to a group of N homogeneously risk averse bidders. At Stage 1 of the game, the sellers each select a first-price or second-price auction. At Stage 2, each bidder learns which auctions have been selected and decides to enter one of the auctions. At Stage 3, the auctions are conducted.

The auction selection game is solved using backward induction. We find that there exists a unique symmetric entry equilibrium that is characterized by a mixed strategy, which depends on the bidders' degree of absolute risk aversion. When choosing between entering the first-price and second-price auction, bidders enter each auction with equal probability if they are risk neutral or exhibit constant absolute risk aversion. However, bidders enter the second-price auction with greater probability if they exhibit decreasing absolute risk aversion, and enter the first-price auction with greater probability if they exhibit increasing absolute risk aversion. Risk averse bidders overbid in first-price auctions but not in second-price auctions, which then implies that competing sellers have a dominant strategy to select first-price auctions when bidders exhibit nondecreasing absolute risk aversion. We demonstrate by example that sellers may also select second-price auctions if bidders exhibit decreasing absolute risk aversion and if the distribution of values is sufficiently skewed.

The results from our study may both be used to explain the reality of online auctioning and to provide guidelines for online auctioneers. That is, our findings suggest that the traditional revenue ranking for risk averse bidders may be reversed if these bidders enter auctions endogenously. To the extent that auctioneers can estimate bidders' degrees of absolute risk aversion and the distribution of values, our results may guide competing auctioneers in their auction selection decisions. For instance, for the empirically relevant case of decreasing absolute risk aversion, a competing auctioneer may select a first-price auction if he expects the distribution of values of the good to be uniform, and may select a second-price auction if he expects this distribution to be more skewed. However, these suggestions should be interpreted with caution, as only a model involving heterogenous bidders could result in concrete recommendations to online auctioneers. Towards the end of Chapter 2, we consider the implications of relaxing the assumption of homogeneity for the entry decisions of bidders. A different extension involves assuming that all units of the good are owned by the same seller. In this setting, we find that the seller offers all units in first-price auctions.

Understanding preferences for ascending auctions, Buy-It-Now auctions and posted prices

The study of endogenous entry into auctions is continued in Chapter 3, which considers both non-standard auctions and non-standard preferences. By means of an exploratory experiment, we analyze entry decisions between three types of selling mechanisms that are frequently found on the Internet: ascending auctions, Buy-It-Now auctions and posted prices. We examine which selling mechanism is preferred by consumers in general and additionally study what drives these preferences. In our experiment, we gather data on entry decisions between three pairs of selling mechanisms: posted price versus ascending auction, posted price versus Buy-It-Now auction, and Buy-It-Now auction versus ascending auction. To examine whether and how entry decisions are affected by monetary and non-monetary incentives, we control for expected payoffs of buying versus bidding and for a number of consumer characteristics, i.e., risk aversion, loss aversion, impatience, sensation seeking and regret.

We find that the posted price is entered considerably less often than the auctions. Furthermore, our findings indicate that entry decisions between selling mechanisms are indeed impacted by expected payoffs. We find that, for a given posted or Buy-It-Now price, subjects are more likely to enter a mechanism which involves bidding when values are below some cut-off, and more likely to enter a mechanism which involves buying when values are above this cut-off. We further find that impatience has a negative impact on the likelihood of entering an ascending auction and risk aversion has a positive impact on the likelihood of entering a mechanism involving bidding. We additionally find that males are more likely to enter a mechanism involving bidding, and that females are more likely to enter a mechanism involving buying.

These results underline that competing sellers should take into account how the selling mechanisms offered affect potential consumers' entry decisions. After all, the format of the selling mechanism does not only affect how many consumers a seller attracts, but also which types of consumers he attracts. A particularly interesting finding of Chapter 3 is the existence of a gender difference in entry decisions. In recent years, a literature on gender differences in competitive preferences has developed, showing that females shy away from competition and that males embrace it. Our finding contributes to this literature, but is also of interest to auctioneers as they may make their choice for a selling mechanism dependent on whether a more feminine or masculine group of potential consumers is expected.

Social comparison concerns in auctions

The success of auctions has often been attributed to the presence of social competition, as this creates an exciting environment and may trigger emotional responses not present in other selling mechanisms. Chapter 4 therefore explores how the presence of social competition may affect bidding behavior in auctions. More specifically, we theoretically study how the anticipated emotions from the social comparison process affect bidding strategies in first-price and second-price auctions, and relate this to experimental and empirical observations. In doing so, we adopt a model of interdependent preferences, where bidders compare their payoffs to some social referent or reference group and may attach different weights to upward and downward comparisons. We assume that bidders experience envy when making upward comparisons, and experience pride when making downward comparisons.

We find that social comparison concerns result in more competitive bidding behavior in both first-price and second-price auctions, and additionally show that this effect is driven by the anticipation of envy. In fact, anticipating envy is a necessary condition to generate overbidding, and the amount of overbidding is increasing in envy. In contrast, anticipating pride does not generate overbidding in isolation, but mitigates the effect of envy. That is, if bidders are both proud and envious, the amount of overbidding is decreasing in pride. We further find that the second-price auction generates higher expected revenues than the first-price auction when bidders are concerned with social comparisons.

Our findings imply that any auctioneer who wants to maximize revenues should frame his auctions to emphasize social losses. This could be achieved, for instance, by pointing out the competitive nature of the auction, by referring to winners and losers, or by displaying personal profiles of the bidders present in an online auction. Furthermore, in an extension of Chapter 4 we consider the implications of assuming that bidders experience guilt instead of pride when making downward comparisons. Though it is questionable whether this is a realistic assumption in highly competitive environments such as auctions, we show that anticipating guilt leads to even more overbidding. Auctioneers may therefore experiment with emphasizing guilt as well as envy in their auctions.

5.2 Directions for future research

In the concluding sections of the preceding chapters, we have already identified limitations and offered suggestions for possible extensions of our research. We do not intend to repeat all these extensions here. Rather, this section presents avenues for future research that are of more general nature. Though the research in this dissertation is already relevant to auctioneers, it may benefit from further extensions towards a more realistic setting. Those would provide better understanding of the workings of online and offline auctions, as well as more concrete implications for auctioneers. The directions for future research presented in this section are thus intended to offer a more real-world perspective on auctions with competing sellers and behavioral bidders.

The research in this dissertation takes a somewhat stylized approach, focusing in Chapters 2 and 4 on homogeneous bidders in first-price and second-price auctions. A straightforward suggestion for further research would thus be to introduce more realism in the models by assuming that bidders are heterogeneous. In general, assuming heterogeneity results in more accurate predictions about bidding behavior, which may be used as a benchmark for experimental and empirical testing. Additionally, incorporating heterogeneity leads to a more complete framework of endogenous entry into competing auctions. Allowing for heterogeneous bidders does not only affect how these bidders distribute over auctions, but could also affect the auction selection decisions of competing auctioneers in unexpected ways. After all, heterogeneous bidders may have heterogeneous preferences over auctions and may show heterogeneous bidding behavior in different auction formats. Thus, when choosing which auction to offer, an auctioneer should not only take into account how many bidders a certain auction format will attract, but also which types of bidders this will attract. Towards the end of Chapter 2, we discuss how relaxing the assumption of homogeneity affects the entry decision between the first-price and second-price auction. Though the approach in this section is again rather stylized, it provides a starting point for modeling competing auctions with heterogeneous bidders.

If heterogeneous bidders have heterogeneous preferences over selling mechanisms, the mechanism through which a good is sold may itself become the subject of differentiation or versioning. On the positive side, such increased differentiation better meets bidders' heterogeneous preferences.

On the negative side, it creates market power through auction differentiation. A discriminating monopolistic auctioneer may simultaneously offer several auctions designed such that different types of bidders self-select into different auctions. Versioning then takes place to introduce hurdles that discourage certain types of bidders of switching to another auction. Future research may develop a theory of auction versioning and may study how this can be used to enhance bidder satisfaction and to increase revenues to the disadvantage of the bidders. At the same time, such a theory could provide insights into how auctions should be regulated. While traditional, offline auctions are regulated by laws designed to protect bidders, these are not applied equivalently to online auctions. Moreover, regulation with respect to auction versioning is absent. Future research may identify which aspects of auction versioning need to be regulated and whether regulation needs to distinguish between online and offline auctions.

Another avenue for future research involves incorporating a broader range of non-standard preferences into auction theory. Many non-standard preferences may still be considered in the context of auctions in general, and in the context of entry into competing auctions in particular. A line of research we strongly believe in involves the integration of prospect theory into auction theory. In the context of a laboratory experiment, both Isaac and James (2000) and Berg et al. (2005) observe that the same bidders behave in a risk averse or risk loving manner depending on the auction format that is used. This implies that auctions are not merely mechanisms that adapt to bidders' preferences, but that they also shape bidders' preferences. We propose prospect theory as an explanation for this phenomenon, as this theory typically assumes that decision makers are risk averse when perceiving gains with respect to their reference points, and are risk loving when perceiving losses (Kahneman and Tversky, 1979). The theories of reference-dependent preferences in auctions by Rosenkranz and Schmitz (2007) and Ahmad (2015) provides a starting point here. Incorporating prospect theory into auctions could additionally provide insights into how auctions can be framed. In Chapter 4, we point out that auctions should be framed to emphasize social losses. However, models with reference-dependent preferences predict that bidders overbid for gains and underbid for losses. This suggests that auctions should be framed to emphasize gains. Future research may attempt to disentangle these approaches. Furthermore, for endogenous entry into competing auctions, it follows that if entry into an auction affects bidders' reference points, this may affect bidders' preferences over auctions. This could explain why some bidders always prefer to use the same auction formats.

In Chapter 3, we rely on data gathered in a laboratory experiment. While the rise of online auctions has arguably led to an increase in the volume of data recorded, this data is not widely available to researchers. Some researchers have used data from eBay (e.g. Bajari and Hortacsu, 2003, 2004), thereby providing insights into actual bidding behavior of actual bidders in actual auctions. Future research may make more use of field data, but may also invest in designing field experiments (e.g. Lucking-Reiley, 1999; List and Lucking-Reiley, 2000). After all, online auctions are relativity inexpensive to conduct and can easily be manipulated to test various experimental conditions. A critical drawback of using field data or field experiments, however, is that researchers have no information about the values of bidders. Additionally, there may be uncertainty about whether values are private or interdependent, and whether the distribution of values is independent or affiliated. Therefore, future research could bring the field into the laboratory, by modeling auctions after those found on the Internet and using a population that is typically found in these auctions (e.g. Grebe et al., 2010). Testing predictions from auction theory in more realistic experimental settings could provide further insights into the behavior bidders and sellers in auctions, which may inspire the development of new theories and thereby lead to a better understanding of auctions.

With this dissertation, we contribute to the advancement of auction theory and to an improvement of the relevance of scientific findings for the field of online auctioning. We achieve this by studying various aspects of non-standard preferences, non-standard auctions and endogenous entry in auctions. Yet, there are still many possibilities for further extending this research. In the future, we hope to explore some of these possibilities and thereby continue to contribute to the knowledge of auctions with competing sellers and behavioral bidders.

Appendix A

Appendix to Chapter 2

A.1 Additions and proofs

Lemma A.1 *The RHS of* (2.1) *is continuous and monotonically increasing in q for a given r.*

Proof. This proof follows the same line of reasoning as the proof of Lemma 1 by Pevnitskaya (2004, p.6). For simplicity we rewrite the RHS of (2.1) as

$$\sum_{n_2=1}^{N} p_{n_2-1:N-1}(q) * x_{n_2}$$

where $p_{n_2-1:N-1}(q) = \binom{N-1}{n_2-1}(1-q)^{n_2-1}(q)^{N-n_2}$ and $x_{n_2} = E[u|a_2, n_2]$. For a given risk parameter, r, among N elements of the sum only the expression $(1-q)^{n_2-1}(q)^{N-n_2}$ is a function of q. Since it is continuous in q, the sum of N elements is continuous in q as well. To show that the RHS of (2.1) is increasing in q for a given r, we therefore only need to prove that

$$\sum_{n_2=1}^{N} [p_{n_2-1:N-1}(q_1) - p_{n_2-1:N-1}(q_2)]x_{n_2} > 0 \qquad \text{for } q_1 > q_2$$

To prove by contradiction, assume that

$$\sum_{n_2=1}^{N} [p_{n_2-1:N-1}(q_1) - p_{n_2-1:N-1}(q_2)]x_{n_2} \leq 0 \qquad \text{for } q_1 > q_2$$

From the binomial density function properties we know that $p_{n_2-1:N-1}(q_1) > p_{n_2-1:N-1}(q_2)$ for small n_2, and vice versa for large n_2. Therefore, there exists some η, such that $[p_{n_2-1:N-1}(q_1) - p_{n_2-1:N-1}(q_2)]x_{n_2} \geq 0$ for any

$n_2 \leq \eta$, and $[p_{n_2-1:N-1}(q_1) - p_{n_2-1:N-1}(q_2)]x_{n_2} < 0$ for any $n_2 > \eta$. The equation above can be rewritten as follows.

$$\sum_{n_2=1}^{\eta} [p_{n_2-1:N-1}(q_1) - p_{n_2-1:N-1}(q_2)]x_{n_2} \leq \sum_{n_2=\eta+1}^{N} [-(p_{n_2-1:N-1}(q_1) - p_{n_2-1:N-1}(q_2))]x_{n_2}$$

Since x_{n_2} is decreasing in n_2, we further have

$$\sum_{n_2=1}^{\eta} [p_{n_2-1:N-1}(q_1) - p_{n_2-1:N-1}(q_2)]x_{n_{\eta+1}} < LHS \leq RHS \leq \sum_{n_2=\eta+1}^{N} [-(p_{n_2-1:N-1}(q_1) - p_{n_2-1:N-1}(q_2))]x_{n_{\eta+1}}$$

This implies the following:

$$\sum_{n_2=1}^{\eta} p_{n_2-1:N-1}(q_1) - \sum_{n_2=1}^{\eta} p_{n_2-1:N-1}(q_2) < \sum_{n_2=\eta+1}^{N} p_{n_2-1:N-1}(q_2) - \sum_{n_2=\eta+1}^{N} p_{n_2-1:N-1}(q_1)$$

This can be rewritten as follows:

$$\sum_{n_2=1}^{N} p_{n_2-1:N-1}(q_1) < \sum_{n_2=1}^{N} p_{n_2-1:N-1}(q_2)$$

$$1 < 1$$

which is a contradiction. Therefore, the assumption does not hold and Lemma A.1 is proven. □

Lemma A.2 *$E[R_{FPA}]$ is continuous and monotonically increasing in q for a given r.*

Proof. Recall that the expected revenue of the FPA is given by

$$E[R_{FPA}] = \sum_{n_1=0}^{N} p_{n_1:N}(q) R_{FPA}(n_1, r)$$

where $p_{n_1:N}(q) = \binom{N}{n_1}(q)^{n_1}(1-q)^{N-n_1}$. For a given risk parameter, r, among N elements of the sum only the expression $(q)^{n_1}(1-q)^{N-n_1}$ is a function of q. Since it is continuous in q, then the sum of N elements is continuous as well. To show that Π_{FPA} is increasing in q for a given r, we only need to prove that

$$\sum_{n_1=0}^{N}[p_{n_1:N}(q_1) - p_{n_1:N}(q_2)]R_{FPA}(n_1, r) > 0 \qquad \text{for } q_1 > q_2$$

To prove by contradiction, assume that

$$\sum_{n_1=0}^{N}[p_{n_1:N}(q_1) - p_{n_1:N}(q_2)]R_{FPA}(n_1, r) \leq 0 \qquad \text{for } q_1 > q_2$$

From the binomial density function properties we know that $p_{n_1:N}(q_1) < p_{n_1:N}(q_2)$ for small n_1, and vice versa for large n_1. Therefore, there exists some η, such that $[p_{n_1:N}(q_1) - p_{n_1:N}(q_2)]R_{FPA}(n_1, r) \leq 0$ for any $n_1 \leq \eta$, and $[p_{n_1:N}(q_1) - p_{n_1:N}(q_2)]R_{FPA}(n_1, r) > 0$ for any $n_1 > \eta$. The equation above can be rewritten as follows.

$$\sum_{n_1=0}^{\eta}[p_{n_1:N}(q_1) - p_{n_1:N}(q_2)]R_{FPA}(n_1, r)$$
$$\leq \sum_{n_1=\eta+1}^{N}[-(p_{n_1:N}(q_1) - p_{n_1:N}(q_2))]R_{FPA}(n_1, r)$$

Since $R_{FPA}(n_1, r)$ is increasing in n_1, we further have

$$\sum_{n_1=0}^{\eta}[p_{n_1:N}(q_1) - p_{n_1:N}(q_2)]R_{FPA}(n_{\eta+1}, r) < LHS$$
$$\leq RHS \leq \sum_{n_1=\eta+1}^{N}[-(p_{n_1:N}(q_1) - p_{n_1:N}(q_2))]R_{FPA}(n_{\eta+1}, r)$$

This implies the following:

$$\sum_{n_1=0}^{\eta} p_{n_1:N}(q_1) - \sum_{n_1=0}^{\eta} p_{n_1:N}(q_2) < \sum_{n_1=\eta+1}^{N} p_{n_1:N}(q_2) - \sum_{n_1=\eta+1}^{N} p_{n_1:N}(q_1)$$
$$\sum_{n_1=0}^{N} p_{n_1:N}(q_1) < \sum_{n_1=0}^{N} p_{n_1:N}(q_2)$$
$$1 < 1$$

which is a contradiction. Therefore, the assumption does not hold and Lemma A.2 is proven. □

Lemma A.3 *$E[R_{SPA}]$ is continuous and monotonically decreasing in q for a given r.*

Proof. Recall that the expected revenue of the FPA is given by

$$E[R_{SPA}] = \sum_{n_2=0}^{N} p_{n_2:N}(q) R_{SPA}(n_2)$$

where $p_{n_2:N}(q) = \binom{N}{n_2}(1-q)^{n_2}(q)^{N-n_2}$. For a given risk parameter, r, among N elements of the sum only the expression $(1-q)^{n_2}(q)^{N-n_2}$ is a function of q. Since it is continuous in q, then the sum of N elements is continuous as well. To show that Π_{SPA} is decreasing in q for a given r, we only need to prove that

$$\sum_{n_2=0}^{N} [p_{n_2:N}(q_1) - p_{n_2:N}(q_2)] R_{SPA}(n_2) < 0 \qquad \text{for } q_1 > q_2$$

To prove by contradiction, assume that

$$\sum_{n_2=0}^{N} [p_{n_2:N}(q_1) - p_{n_2:N}(q_2)] R_{SPA}(n_2) \geq 0 \qquad \text{for } q_1 > q_2$$

From the binomial density function properties we know that $p_{n_2:N}(q_1) > p_{n_2:N}(q_2)$ for small n_2, and vice versa for large n_2. Therefore, there exists some η, such that $[p_{n_2:N}(q_1) - p_{n_2:N}(q_2)]R_{SPA}(n_2) \geq 0$ for any $n_2 \leq \eta$, and $[p_{n_2:N}(q_1) - p_{n_2:N}(q_2)]R_{SPA}(n_2) > 0$ for any $n_2 > \eta$. The equation above can be rewritten as follows.

$$\sum_{n_2=0}^{\eta} [p_{n_2:N}(q_1) - p_{n_2:N}(q_2)] R_{SPA}(n_2) \geq \sum_{n_2=\eta+1}^{N} [-(p_{n_2:N}(q_1) - p_{n_2:N}(q_2))] R_{SPA}(n_2)$$

Since $R_{SPA}(n_2)$ is increasing in n_2, we further have

$$\sum_{n_2=0}^{\eta} [p_{n_2:N}(q_1) - p_{n_2:N}(q_2)] R_{SPA}(n_{\eta+1}) > LHS \geq RHS \geq \sum_{n_2=\eta+1}^{N} [-(p_{n_2:N}(q_1) - p_{n_2:N}(q_2))] R_{SPA}(n_{\eta+1})$$

This implies the following:

$$\sum_{n_2=0}^{\eta} p_{n_2:N}(q_1) - \sum_{n_2=0}^{\eta} p_{n_2:N}(q_2) > \sum_{n_1=\eta+1}^{N} p_{n_2:N}(q_2) - \sum_{n_2=\eta+1}^{N} p_{n_1:N}(q_1)$$

$$\sum_{n_2=0}^{N} p_{n_2:N}(q_1) > \sum_{n_2=0}^{N} p_{n_2:N}(q_2)$$

$$1 > 1$$

which is a contradiction. Therefore, the assumption does not hold and Lemma A.3 is proven. $\square$

A.2 Example with CRRA bidders

Suppose that bidder i has a utility function of the form $u(m_i) = m_i^{(1-\rho)}$, where m_i represents i's payoff and $\rho \in [0,1)$ represents the coefficient of CRRA. Further suppose that values are distributed according to $F(v) = v^\alpha$ for $v \in [0,1]$, where $\alpha \geq 1$ and takes integer values only. From Smith and Levin (1996), we know that the symmetric equilibrium in FPA is then given by the bidding strategy

$$b^{FPA}(v) = \frac{\alpha(n_l-1)}{\alpha(n_l-1)+1-\rho}v$$

The ex ante expected revenue of the FPA is given by

$$\begin{aligned}
R_{FPA}(n_l,r) &= \int_0^1 n_l\left(\frac{\alpha(n_l-1)}{\alpha(n_l-1)+1-\rho}v\right)\alpha v^{\alpha-1}v^{\alpha(n_l-1)}dv \\
&= \alpha n_l \frac{\alpha(n_l-1)}{\alpha(n_l-1)+1-\rho}\int_0^1 v^{\alpha n_l}dv \\
&= \alpha n_l \frac{\alpha(n_l-1)}{\alpha(n_l-1)+1-\rho}\left[\frac{1}{\alpha n_l+1}v^{\alpha n_l+1}\right]_0^1 \\
&= \frac{\alpha(n_l-1)}{\alpha(n_l-1)+1-\rho}\frac{\alpha n_l}{\alpha n_l+1}
\end{aligned}$$

Given that there are n_l bidders in the auction, each bidder then has an ex ante expected utility of

$$\begin{aligned}
E[u|FPA,n_l] &= \int_0^1 \alpha v^{\alpha-1}v^{\alpha(n_l-1)}\left(v-\frac{\alpha(n_l-1)}{\alpha(n_l-1)+1-\rho}v\right)^{1-\rho}dv \\
&= \alpha\left(\frac{1-\rho}{\alpha(n_l-1)+1-\rho}\right)^{1-\rho}\int_0^1 v^{\alpha n_l-\rho}dv \\
&= \alpha\left(\frac{1-\rho}{\alpha(n_l-1)+1-\rho}\right)^{1-\rho}\left[\frac{1}{\alpha n_l+1-\rho}v^{\alpha n_l+1-\rho}\right]_0^1 \\
&= \frac{\alpha}{\alpha n_l+1-\rho}\left(\frac{1-\rho}{\alpha(n_l-1)+1-\rho}\right)^{1-\rho}
\end{aligned}$$

For the SPA, the symmetric equilibrium is to bid one's own private value, that is, $b^{SPA}(v) = v$. The ex ante expected revenue of the SPA is then given by

$$\begin{aligned}
R_{SPA}(n_l) &= \int_0^1 n_l(n_l-1)v\alpha v^{\alpha-1}v^{\alpha(n_i-2)}\left[1-v^{\alpha}\right]dv \\
&= \alpha n_l(n_l-1)\int_0^1 v^{\alpha(n_l-1)}(1-v^{\alpha})dv \\
&= \alpha n_l(n_l-1)\left\{\left[\frac{1}{\alpha(n_l-1)+1}v^{\alpha(n_l-1)+1}\right]_0^1 - \left[\frac{1}{\alpha n_l+1}v^{\alpha n_l+1}\right]_0^1\right\} \\
&= \frac{\alpha(n_l-1)}{\alpha(n_l-1)+1}\frac{\alpha n_l}{\alpha n_l+1}
\end{aligned}$$

Following Smith and Levin (1996), we show that, given that there are n_l bidders in the auction, each bidder has an ex ante expected utility of

$$\begin{aligned}
E[u|SPA, n_l] &= \int_0^1 \left[\alpha(n_l-1)\int_0^v t^{\alpha(n_l-1)-1}(v-t)^{1-\rho}\,dt\right]\alpha v^{\alpha-1}dv \\
&= \frac{\alpha}{\alpha n_l+1-\rho}\frac{(\alpha(n_l-1))!}{(\alpha(n_l-1)+1-\rho)!} \qquad \text{(A.1)}
\end{aligned}$$

where $(\alpha(n_l-1)+1-\rho)! \equiv \prod_{i=1}^{\alpha(n_l-1)}(i+1-\rho)$. To establish (A.1), we start by proving that the term in square brackets in (A.1), which represents the expected utility of a bidder with value v, can be rewritten as follows.

$$\alpha(n_l-1)\int_0^v t^{\alpha(n_l-1)-1}(v-t)^{1-\rho}\,dt = \frac{(\alpha(n_l-1))!}{(\alpha(n_l-1)+1-\rho)!}v^{\alpha(n_l-1)+1-\rho} \qquad \text{(A.2)}$$

Suppose that $\alpha(n_l-1)=1$. Then (A.2) is trivially true.

$$\int_0^v (v-t)^{1-\rho}\,dt = -\frac{1}{2-\rho}\left[t^{2-\rho}\right]_0^v = \frac{1}{2-\rho}v^{2-\rho}$$

Let us now show that (A.2) also holds for $\alpha(n_l-1)=2$. In order to do so, we need to use integration by parts: $\int udv = uv - \int vdu$. Integrating the LHS of (A.2) by parts gives us the following.

$$\begin{aligned}
&-\alpha(n_l-1)\left[\frac{1}{2-\rho}t^{\alpha(n_l-1)-1}(v-t)^{2-\rho}\right]_0^v \\
&\quad + \alpha(n_l-1)\frac{\alpha(n_l-1)-1}{2-\rho}\int_0^v t^{\alpha(n_l-1)-2}(v-t)^{2-\rho}dt \\
&\quad = \frac{\alpha(n_l-1)(\alpha(n_l-1)-1)}{2-\rho}\int_0^v t^{\alpha(n_l-1)-2}(v-t)^{2-\rho}dt \qquad \text{(A.3)}
\end{aligned}$$

Now suppose that $\alpha(n_l-1)=2$. The RHS of (A.3) then becomes

$$\begin{aligned}\frac{\alpha(n_l-1)(\alpha(n_l-1)-1)}{2-\rho}&\int_0^v (v-t)^{2-\rho}dt\\ &= -\frac{\alpha(n_l-1)(\alpha(n_l-1)-1)}{2-\rho}\left[\frac{1}{3-\rho}(v-t)^{3-\rho}\right]_0^v\\ &= \frac{2*1}{(2-\rho)(3-\rho)}v^{3-\rho}\end{aligned}$$

which proves that (A.2) holds for $\alpha(n_l-1)=2$ as well. Having verified (A.2) for $\alpha(n_l-1)=\{1,2\}$ we now prove by induction. Assume that (A.2) holds for $\alpha(n_l-1)=k$.

$$k\int_0^v t^{k-1}(v-t)^{1-\rho}\,dt = \frac{k!}{(k+1-\rho)!}v^{k+1-\rho} \tag{A.4}$$

Now, we can show that (A.2) also holds for $\alpha(n_l-1)=k+1$. That is, we want to prove the following.

$$(k+1)\int_0^v t^{k}(v-t)^{1-\rho}\,dt = \frac{(k+1)!}{((k+1)+1-\rho)!}v^{(k+1)+1-\rho} \tag{A.5}$$

We start by integrating the LHS of (A.5). This gives us the following.

$$\begin{aligned}(k+1)&\left\{-\left[\frac{1}{2-\rho}t^k(v-t)^{2-\rho}\right]_0^v+\frac{k}{2-\rho}\int_0^v t^{k-1}(v-t)^{2-\rho}dt\right\}\\ &= \frac{(k+1)}{(2-\rho)}\left\{k\int_0^v t^{k-1}(v-t)^{2-\rho}dt\right\}\end{aligned}$$

We now use A.4 to rewrite this as follows.

$$\frac{(k+1)}{(2-\rho)}\left\{\frac{k!}{(k+2-\rho)!}v^{k+2-\rho}\right\}=\frac{(k+1)!}{(k+2-\rho)!}v^{k+2-\rho}$$

This establishes (A.5) and concludes the proof of (A.2). Therefore, we can write the ex ante expected utility, where the bidder does not know her private value yet, as follows.

$$\begin{aligned}E[u|SPA,n_l] &= \int_0^1\left[\frac{(\alpha(n_l-1))!}{(\alpha(n_l-1)+1-\rho)!}v^{\alpha(n_l-1)+1-\rho}\right]\alpha v^{\alpha-1}dv\\ &= \alpha\frac{(\alpha(n_l-1))!}{(\alpha(n_l-1)+1-\rho)!}\int_0^1 v^{\alpha n_l-\rho}dv\\ &= \alpha\frac{(\alpha(n_l-1))!}{(\alpha(n_l-1)+1-\rho)!}\left[\frac{1}{\alpha n_l+1-\rho}v^{\alpha n_l+1-\rho}\right]_0^1\\ &= \frac{\alpha}{\alpha n_l+1-\rho}\frac{(\alpha(n_l-1))!}{(\alpha(n_l-1)+1-\rho)!}\end{aligned} \tag{A.6}$$

This concludes the proof of (A.1).

Notice that when bidders are risk averse ($\rho = 0$), then the FPA and SPA are both revenue and utility equivalent.

$$\begin{aligned} R_{FPA}(n_l, 0) &= \frac{\alpha(n_l - 1)}{\alpha(n_l - 1) + 1 - 0} \frac{\alpha n_l}{\alpha n_l + 1} \\ &= \frac{\alpha(n_l - 1)}{\alpha(n_l - 1) + 1} \frac{\alpha n_l}{\alpha n_l + 1} = R_{SPA}(n_l) \end{aligned}$$

$$\begin{aligned} E[u|FPA, n_l] &= \frac{\alpha}{\alpha n_l + 1 - 0} \left(\frac{1 - 0}{\alpha(n_l - 1) + 1 - 0} \right)^{1-0} \\ &= \frac{(\alpha(n_l - 1))!}{(\alpha(n_l - 1) + 1 - 0))!} \frac{\alpha}{\alpha n_l + 1 - 0} = E[u|SPA, n_l] \end{aligned}$$

Appendix B

Appendix to Chapter 3

B.1 Instructions

You are participating in an economics experiment. Please read the following instructions carefully. These instructions state everything you need to know in order to participate in the experiment, and they are identical for all participants in the experiment. If you have any questions, please raise your hand. One of the experimenters will approach you in order to answer your question. You can earn money by means of earning points during the experiment. The number of points that you earn depends on your own choices and the choices of other participants. At the end of the experiment, the total number of points that you earn during the experiment will be exchanged at an exchange rate of:

$$25 \text{ points} = €\,1$$

The money you earn will be paid out anonymously and in cash at the end of the experiment. The other participants will not see what you earn. Further instructions on this will follow below and on the computer screen. During the experiment you are not allowed to communicate with other participants and you are not allowed to use your cell phone. Also, you may only use the functions of the PC necessary for the experiment.

Overview of the experiment

The experiment will consist of two phases. After reading this set of instructions, you will receive instructions for phase 1 and this phase will start. After completing the first phase, you will be handed a new set of instructions for phase 2. After completing both phases, you will be asked to participate in some short additional decision making tasks and to fill in a questionnaire. In this set of instructions you can find general information about the experiment.

In this experiment you can earn points by participating in a series of games or mechanisms. In each mechanism you will compete with one other participant to earn points. Only one of you can win these points. If you are the winner, you will receive a payoff which is equal to your value (which is given to you by the computer) minus the price (which is determined differently in each mechanism). Note that this payoff may also be negative. For example, if you have a value of 40 and a price of 25, you will earn 15 points. Likewise, if you have a value of 25 and a price of 40, you will earn -15 points. If you lose, you will receive no points. Thus, the number of points you can earn in a mechanism is:

If you win:	value - price
If you lose:	0

During the experiment you will remain anonymous. You will not get to know the identity of the other participant in your pair, neither during the experiment nor after the experiment. The other participants will also not know your identity.

Value

For you and for each other participant the computer separately draws a value from the interval [0,100], where each value is equally likely. You are informed only about your own private value and have no information on the values of the other participants. Note that your value does not provide any information on the values of the other participants, since values are randomly drawn from the interval [0, 100] for each participant separately.

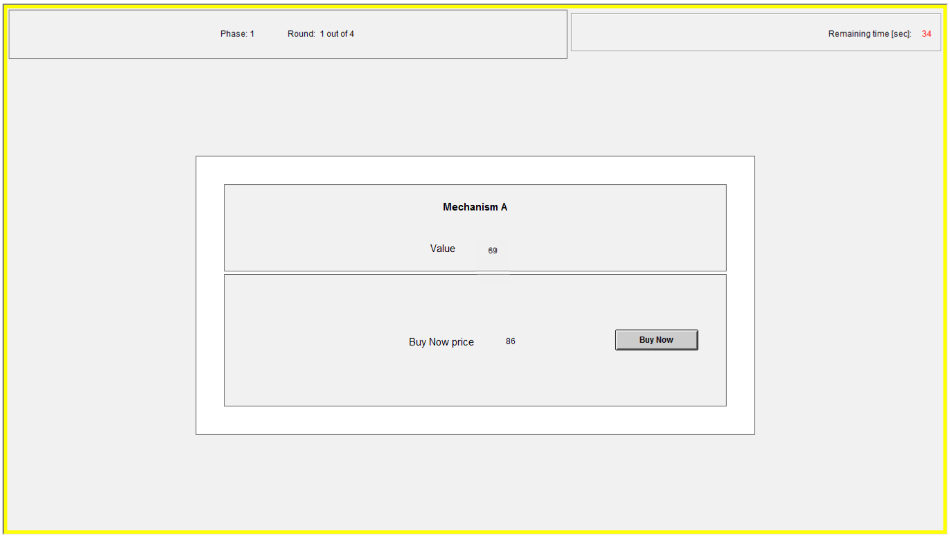
Mechanisms

In each mechanism the rules for winning are different. Furthermore, the price is determined differently in each mechanism. In some mechanisms you have the opportunity to influence the price, whereas in others you cannot. You always have 45 seconds to choose your actions, which determine both whether you win or lose and the price you have to pay. On the following pages these mechanisms are explained in more detail. Please make yourself familiar with these mechanisms and keep these descriptions next to your computer, so that you can check them if necessary.

Mechanism A

In mechanism A you can win points by pushing a Buy Now button. The first participant in your pair to push the Buy Now button will win and earn a payoff equal to his or her value, minus some fixed price. This fixed price is set by the computer and is between 0 and 100. If the price is higher than the winner's value he or she receives a negative payoff. Thus, in some instances it may be better not to attempt to win. In case both participants push the Buy Now button simultaneously, the winner will be picked randomly. If no participant pushes the Buy Now button within 45 seconds, both players lose and receive no points.

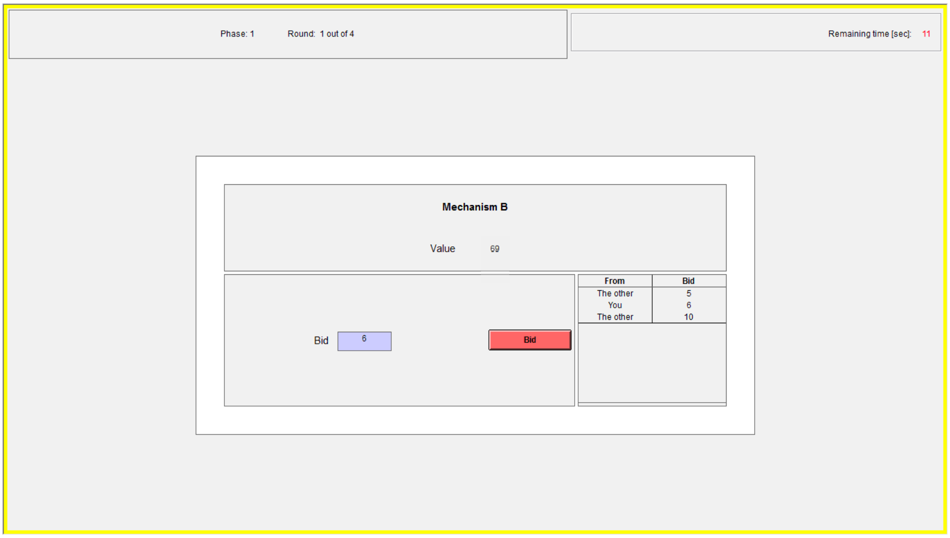
On the screen you can see your current value, the Buy Now price, the phase and round you are currently in and the time remaining for you to make your choice. In order to make sure you have enough time to inspect your value and the Buy Now price, you can only push the button after 3 seconds. The time remaining is shown in the upper right corner of the screen.



Mechanism B

In mechanism B you have the opportunity to influence the price the winner pays, by placing bids. During 45 seconds, you and the other participant are allowed to place bids, which may be any number from 0 up to 150 and can only include integer values (1, 2, ..., 150). You can only place a bid that is at least 1 point higher than the previous bid. After 45 seconds, the participant with the highest bid will be the winner and pays a price equal to his or her highest bid. If no participant ever places a bid, none of the participants will receive points.

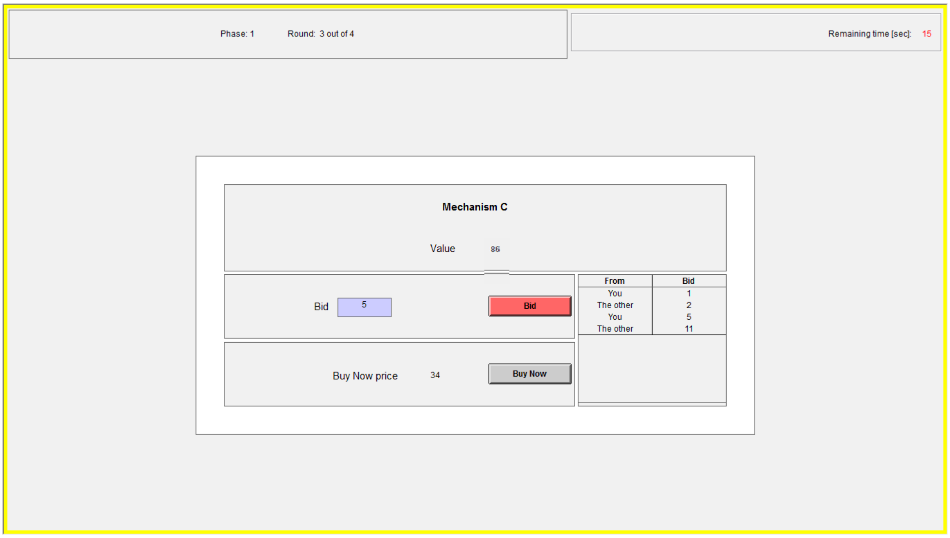
On the screen you can again see your current value, the phase and round you are currently in and the time remaining to place your bids. Additionally, you can see the bidding history of you and the other participant and the current highest bid. Again, you can only start bidding after 3 seconds.



Mechanism C

In mechanism C the computer again sets a fixed price between 0 and 100. You can either choose to accept this fixed price by pushing the Buy Now button or to set the price yourself by placing bids. Again, you are only allowed to place a bid between 0 and 150 (1, 2, ..., 150) and bids should be at least 1 point higher than the most recent bid. As soon as any participant pushes the Buy Now button, this participant will win and the mechanism ends. If no participant pushes the Buy Now button within 45 seconds, the participant with the highest bid wins and pays a price equal to his or her highest bid. If no participant ever pushes the Buy Now button or places a bid, none of the players will receive points.

On the screen you can see your current value, the Buy Now price, the phase and round you are currently in and the remaining time. At any time, you see on the screen all of the previous bids, including your own previous bids and those of the other participant. You can only start bidding or push the Buy Now button after 3 seconds.

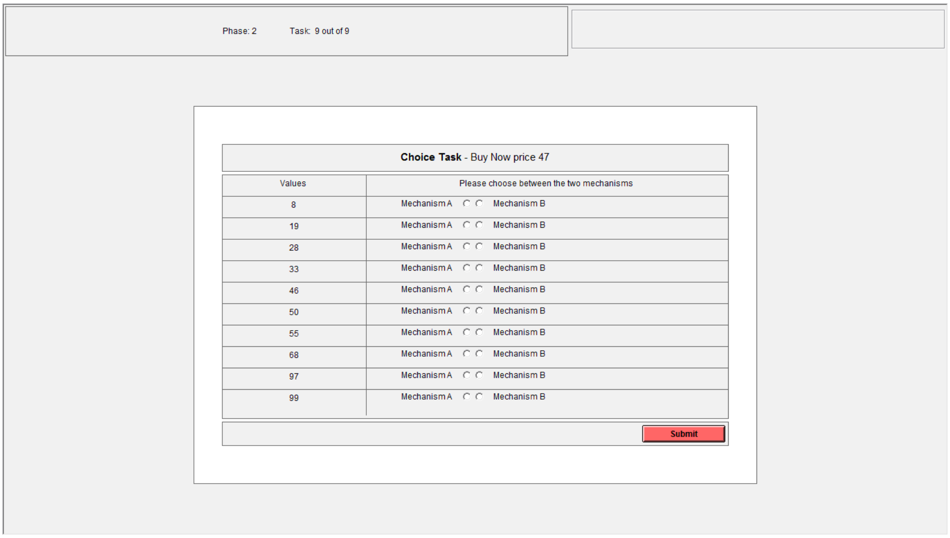


Phase 1

In the first phase you will participate in a series of mechanisms. You will participate in four rounds. In each round of this phase you will play three mechanisms (mechanism A, B and C), which will be presented in varying order. At the start of each round you will be informed of your value and the Buy Now price. You will be randomly matched with one other participant in each round, so it is likely that you will compete with a different participant each time. After you have played all three mechanisms a new Buy Now price, value and participant to which you are paired will be selected and the new round begins. At the conclusion of this phase you will be informed about your total points earned so far.

Phase 2

In this phase you will encounter nine different choice tasks. In every choice task you will be asked to choose between two mechanisms. You will have to choose three times between mechanisms A and B, three times between A and C, and three times between B and C. The order in which these choice tasks are presented is varied. A single choice task will look as follows.



In every choice task you will receive a list of ten randomly drawn values that you may potentially have, and for each value you are asked to choose between the two mechanisms. During the choice task you can see the Buy Now price on the screen, which you will have to pay if you push the Buy Now button in mechanism A or mechanism C. The Buy Now price is chosen by the computer and is the same for all participants. All participants face the same choices. After all participants have indicated their choices, each participant is randomly assigned one of the values in his or her list. You will then play the mechanism of your choice for this value, with a participant that has chosen the same mechanism. If it is not possible to find a participant with the same preference, you may not end up playing the mechanism of your choice. This is done in order to ensure that everyone participates in a mechanism. Finally, the chosen mechanism is played in exactly the same way as in phase 1. After this has been completed, you will receive a new choice task between two mechanisms with a new random Buy Now price and a new list of ten values, and where the choice task proceeds as before.

B.2 Psychometric measures and summary statistics

This section contains additional information about the psychometric measures done during the experiment (Tables B.1 to B.5), as well as pairwise correlations of the variables describing our subjects (Table B.6).

Table B.1: Risk attitude elicitation task based on Holt and Laury (2002)

Task						Measure			
	Option A		Option B		Expected payoff*				
	50	40	96.25	2.5	difference	Safe choices†	Risk classification	Freq.	Percent
1	1/10	9/10	1/10	9/10	29.125	0-1	1. Highly risk loving	1	0.88%
2	2/10	8/10	2/10	8/10	20.750	2	2. Very risk loving	0	0%
3	3/10	7/10	3/10	7/10	12.375	3	3. Risk loving	4	3.51%
4	4/10	6/10	4/10	6/10	4.000	4	4. Risk neutral	12	10.53%
5	5/10	5/10	5/10	5/10	-4.375	5	5. Slightly risk averse	15	13.16%
6	6/10	4/10	6/10	4/10	-12.750	6	6. Risk averse	27	23.68%
7	7/10	3/10	7/10	3/10	-21.125	7	7. Very risk averse	30	26.32%
8	8/10	2/10	8/10	2/10	-29.500	8	8. Highly risk averse	18	15.79%
9	9/10	1/10	9/10	1/10	-37.875	9-10	9. Extremely risk averse	7	6.14%
10	10/10	0/10	10/10	0/10	-46.250				

* Payoffs are given in ECU, where 25 points = €1.

† Attention is restricted to consistent choices.

Table B.2: Loss attitude elicitation task based on Gächter et al. (2010)

Task				Measure			
	Lottery		Expected	Lotteries			
	1/2	1/2	payoff*	rejected†	Loss classification	Freq.	Percent
1	-25	125	50	0	1. Accept all	2	1.75%
2	-50	125	37.5	1	2. Accept 1–5/Reject 6	3	2.63%
3	-75	125	25	2	3. Accept 1–4/Reject 5–6	7	6.14%
4	-100	125	12.5	3	4. Accept 1–3/Reject 4–6	21	18.42%
5	-125	125	0	4	5. Accept 1–2/Reject 3–6	35	30.70%
6	-150	125	-12.5	5	6. Accept 1/Reject 2–6	40	35.09%
				6	7. Reject all	6	5.26%

* Payoffs are given in ECU, where 25 points = €1.

† Attention is restricted to consistent choices.

Table B.3: Money Choice Questionnaire (Kirby et al., 1999)

Option A	Option B
€54 today	€55 in 117 days
€55 today	€75 in 61 days
€19 today	€25 in 53 days
€31 today	€85 in 7 days
€14 today	€25 in 19 days
€47 today	€50 in 160 days
€15 today	€35 in 13 days
€25 today	€60 in 14 days
€78 today	€80 in 162 days
€40 today	€55 in 62 days
€11 today	€30 in 7 days
€67 today	€75 in 119 days
€34 today	€35 in 186 days
€27 today	€50 in 21 days
€69 today	€85 in 91 days
€49 today	€60 in 89 days
€80 today	€85 in 157 days
€24 today	€35 in 29 days
€33 today	€80 in 14 days
€28 today	€30 in 179 days
€34 today	€50 in 30 days
€25 today	€30 in 80 days
€41 today	€75 in 20 days
€54 today	€60 in 111 days
€54 today	€80 in 30 days
€22 today	€25 in 136 days
€20 today	€55 in 7 days

Table B.4: Thrill and adventure seeking subscale of Sensation Seeking Scale V (Zuckerman, 1994)

	Statement A	Statement B
1	I often wish I could be a mountain climber.	I can't understand people who risk their necks climbing mountains.
2 (r)	A sensible person avoids activities that are dangerous.	I would like to try to do things that are a little frightening.
3	I would like to take up the sport of water skiing.	I would not like to take up the sport of water skiing.
4	I would like to try surfing.	I would not like to try surfing.
5 (r)	I would not like to learn to fly an aeroplane.	I would like to learn to fly an aeroplane.
6 (r)	I prefer the surface of the water to the depth.	I would like to go scuba diving.
7	I would like to try parachute jumping.	I would never want to try jumping out of a plane.
8	I like to dive off the high board.	I don't like the feeling I get standing on the high board (or I don't go near it at all).
9 (r)	Sailing long distances in small sailing crafts is foolhardy.	I would like to sail a long distance in a small but seaworthy sailing craft.
10 (r)	Skiing down a high mountain slope is a good way to end up on crutches.	I think I would enjoy the sensation of skiing very fast down a high mountain slope.

Table B.5: Regret Scale (Schwartz et al., 2002)

	Statement
1 (r)	Once I make a decision, I don't look back.
2	Whenever I make a choice, I'm curious about what would have happened if I had chosen differently.
3	Whenever I make a choice, I try to get information about how the other alternatives turned out.
4	If I make a choice and it turns out well, I still feel like something of a failure if I find out that another choice would have turned out better.
5	When I think about how I'm doing in life, I often assess opportunities I have passed up.

Table B.6: Pearson correlations

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Gender[1]	-									
2. Age	0.037	-								
3. Nationality[2]	-0.063	-0.052	-							
4. Students[3]	0.046	-0.533***	0.026	-						
5. Economics[4]	-0.163*	-0.402***	-0.305***	0.265***	-					
6. Online auction[5]	0.002	0.078	0.071	-0.006	-0.075	-				
7. Payoffs P[6]	0.068	0.065	0.028	-0.004	-0.010	0.088	-			
8. Payoffs A[6]	-0.036	0.067	0.177*	0.024	-0.006	-0.047	0.306***	-		
9. Payoffs BIN[6]	-0.072	0.082	0.075	-0.153	0.004	-0.076	0.460***	0.365***	-	
10. Impatience	0.145	-0.093	-0.318***	0.044	0.172*	0.079	-0.104	-0.150	-0.106	-
11. Risk attitude	0.345***	-0.018	-0.077	-0.003	-0.158*	0.045	-0.090	-0.064	-0.161	0.151
12. Loss attitude	0.288***	-0.099	-0.015	0.065	-0.061	-0.072	-0.122	-0.033	-0.110	0.078
13. Sensation seeking	-0.262***	-0.226**	-0.010	0.035	0.199**	-0.105	-0.029	-0.073	0.096	0.067
14. Regret	0.040	0.008	-0.028	-0.103	0.014	0.199	-0.014	-0.025	-0.079	-0.039

	11.	12.	13.	14.
11. Risk attitude	-			
12. Loss attitude	0.355***	-		
13. Sensation seeking	-0.115	-0.241***	-	
14. Regret	-0.023	0.099	-0.195**	-

*** p<0.01, ** p<0.05, * p<0.1

[1] Female=1, male=0.

[2] Dutch=1, non-Dutch=0.

[3] Student=1, non-student=0.

[4] Economics student=1, other=0.

[5] Experience=1, no experience=0.

[6] Payoffs from trading periods played during the learning phase.

Appendix C

Appendix to Chapter 4

Proposition 4.1 *The symmetric equilibrium for bidders with social comparison concerns in first-price auctions is given by the bidding strategy*

$$b^{FPA}(v) = v - \int_0^v \left(\frac{F(t)}{F(v)}\right)^{\frac{(1+\varepsilon)(N-1)+\gamma}{1+\varepsilon}} dt$$

Proof. This proof follows the standard derivation of the equilibrium bidding strategy in a FPA and specifically follows the proof of Theorem 1 by Brandt et al. (2007, p. 1209). Assume that each bidder compares her payoff to the payoffs of all other bidders, such that her utility is defined by (4.2). Bidder i's expected utility is then given by

$$\begin{aligned} E[U_i] = &(1+\varepsilon)\, Pr(W_i)\, (v_i - b_i(v_i)) \\ &- \frac{\gamma}{N-1} Pr(\neg W_i) \left(E[v_{(1)}|\neg W_i] - E[b(v_{(1)})|\neg W_i]\right) \end{aligned}$$

Further assume that the bidding strategies $b(v_j)$ are strictly increasing and differentiable over the value space $[0,1]$. Therefore, i wins the auction whenever $b_i(v_i) > b(v_{(1)})$ or, equivalently, whenever $b^{-1}(b_i(v_i)) > v_{(1)}$. Now, let $\widetilde{v}$ be shorthand for the inverse function of $b_i(v_i)$, such that $Pr(W_i) = F(\widetilde{v})^{N-1}$. Following Brandt et al. (2007), we use probability theory to write the conditional expectations in (4.2) as follows.

$$E[v_{(1)}|\neg W_i] = \frac{1}{1-F(\widetilde{v})^{N-1}} \int_{\widetilde{v}}^1 t(N-1)F(t)^{N-2} f(t)dt$$

$$E[b(v_{(1)})|\neg W_i] = \frac{1}{1-F(\widetilde{v})^{N-1}} \int_{b_i(v_i)}^{b_i(1)} t(N-1)F(\widetilde{v}(t))^{N-2} f(\widetilde{v}(t))\widetilde{v}'(t)dt$$

Therefore, the expected utility of bidder i can be rewritten as follows.

$$E[U_i] = (1+\varepsilon)\, F(\widetilde{v})^{N-1}\,(v_i - b_i(v_i)) - \gamma \int_{\widetilde{v}}^{1} tF(t)^{N-2} f(t)dt \\ + \gamma \int_{b_i(v_i)}^{b_i(1)} tF(\widetilde{v}(t))^{N-2} f(\widetilde{v}(t))\widetilde{v}'(t)dt \tag{C.1}$$

Maximizing (C.1) with respect to $b_i(v_i)$ then yields the first-order condition

$$0 = -\,(1+\varepsilon)F(\widetilde{v})^{N-1} + (1+\varepsilon)(N-1)F(\widetilde{v})^{N-2} f(\widetilde{v})\widetilde{v}'\,(v_i - b_i(v_i)) \\ + \gamma F(\widetilde{v})^{N-2} f(\widetilde{v})\widetilde{v}'\,(\widetilde{v} - b_i(v_i)) \tag{C.2}$$

Using the fact that $\widetilde{v}' = \frac{1}{b_i'(v_i)}$ and that in a symmetric equilibrium $b_i(v_i) = b(v_i)$, such that $\widetilde{v} = b^{-1}(b(v_i)) = v_i$, (C.2) can be rewritten as follows.

$$b'(v) = \frac{(1+\varepsilon)(N-1)+\gamma}{1+\varepsilon} \frac{f(v)}{F(v)}\,(v - b(v)) \tag{C.3}$$

From this differential equation one can already see that $b(v) < v$. Furthermore, as a bidder with zero value would never place a positive bid and negative bids are not possible, $b(0) = 0$. Multiplying by the integrating factor $F(v)^{\frac{(1+\varepsilon)(N-1)+\gamma}{1+\varepsilon}}$ yields the solution

$$b(v) = v - \int_0^v \left(\frac{F(t)}{F(v)}\right)^{\frac{(1+\varepsilon)(N-1)+\gamma}{1+\varepsilon}} dt$$

Following Brandt et al. (2007), this expression is in fact a conditional expectation $b(v) = E[X|X < v]$, where the cumulative distribution function of X is given by $F(x)^{\frac{(1+\varepsilon)(N-1)+\gamma}{1+\varepsilon}}$.

As (C.3) is merely a necessary condition, we now proceed to prove that $b(v)$ is indeed a mutually best response. Suppose that all but bidder i use strategy $b(v)$. We prove that it is optimal for bidder i to also follow strategy $b(v)$. Notice that $b(v)$ is continuous and strictly increasing:

$$b'(v) = \frac{(1+\varepsilon)(N-1)+\gamma}{1+\varepsilon} \frac{f(v)}{F(v)} \int_0^v \left(\frac{F(t)}{F(v)}\right)^{\frac{(1+\varepsilon)(N-1)+\gamma}{1+\varepsilon}} dt > 0.$$

To check that $b(v)$ is indeed an equilibrium, use (C.3) to rewrite the first order condition in (C.2):

$$\frac{f(\widetilde{v})}{F(\widetilde{v})}\left[(1+\varepsilon)(N-1)\,(v_i - b_i(v_i)) + \gamma\,(\widetilde{v} - b_i(v_i))\right] \\ = \frac{f(v_i)}{F(v_i)}\left[(1+\varepsilon)(N-1)+\gamma\right](v_i - b_i(v_i))$$

It can easily be seen that the RHS and LHS are only equal, thereby satisfying the first-order condition, whenever $b_i(v_i) = b(v_i)$. This concludes the proof of Proposition 4.1. □

Corollary 4.1 *In first-price auctions with $N \geq 2$ bidders who have social comparison concerns, the following holds:*

- *If $\gamma = 0$, for any $\varepsilon \geq 0$ the symmetric equilibrium is given by the RNNE bidding strategy.*
- *If $\gamma > 0$, the following results hold:*
  - *(i) Overbidding occurs.*
  - *(ii) The bids and the amount of overbidding are increasing in upward comparison concerns, γ.*
  - *(iii) The bids and the amount of overbidding are decreasing in downward comparison concerns, ε.*
  - *(iv) The bids are increasing in N and the amount of overbidding is decreasing in N.*

Proof. (i), (ii), (iii) and (iv) of Corollary 4.1 all rely on the following argument. Suppose that X and Y are random variables distributed according to the functions F and G, respectively, and that F first order stochastically dominates G for all $v \in [0, 1]$. This implies that the (conditional) expected value of X is greater than or equal to the (conditional) expected value of Y.

To illustrate this, let us compare the bidding strategy for bidders with and without social comparison concerns. To ease the process we first reformulate the bidding strategy $b^{FPA}(v)$ as a function of z:

$$b^{FPA}(v, z) = v - \int_0^v \left(\frac{F(t)}{F(v)} \right)^{(1+z)(N-1)} dt$$

where $z = (\gamma)/((1 + \varepsilon)(N - 1))$. Notice that this is in fact a conditional expectation $b^{FPA}(v, z) = E[X|X < v]$, where the cumulative distribution function of X is given by $F(x)^{(1+z)(N-1)}$. It is easy to see that $z > 0$ for $\gamma > 0$, $\varepsilon \geq 0$ and $N \geq 2$. Furthermore, if $z = 0$ the bidding strategy is equal to the RNNE bidding strategy:

$$b^{FPA}(v, 0) = v - \int_0^v \left(\frac{F(t)}{F(v)} \right)^{(N-1)} dt$$

We can show that for $z > 0$, $\left(\frac{F(t)}{F(v)}\right)^{(1+z)(N-1)}$ first order stochastically dominates $\left(\frac{F(t)}{F(v)}\right)^{(N-1)}$. Recall that this implies that $\left(\frac{F(t)}{F(v)}\right)^{(1+z)(N-1)} \leq \left(\frac{F(t)}{F(v)}\right)^{(N-1)}$.

$$\left(\frac{F(t)}{F(v)}\right)^{(1+z)(N-1)} = \left(\frac{F(t)}{F(v)}\right)^{z(N-1)} \left(\frac{F(t)}{F(v)}\right)^{(N-1)} \leq \left(\frac{F(t)}{F(v)}\right)^{(N-1)}$$

where the inequality follows from the fact that $\frac{F(t)}{F(v)} < 1$ for any $t < v$. It immediately follows that $b^{FPA}(v,z) > b^{FPA}(v,0)$ for any $z > 0$, thereby proving (i) of Corollary 4.1.

In the same way, one can check that for any $0 < z' < z''$ the distribution function $F(x)^{(1+z'')(N-1)}$ first order stochastically dominates $F(x)^{(1+z')(N-1)}$. Hence, an increase in z must lead to an increase in $b^{FPA}(v,z)$. To prove (ii) and (iii) of Corollary 4.1, we therefore only need to show that for $N \geq 2$ an increase in γ leads to an increase in z, and that for $N \geq 2$ and $\gamma > 0$ an increase in ε leads to a decrease in z:

$$\frac{\partial z}{\partial \gamma} = \frac{1}{(1+\varepsilon)(N-1)}$$
$$\frac{\partial z}{\partial \varepsilon} = -\frac{\gamma(N-1)}{((1+\varepsilon)(N-1))^2}$$

This proves (ii) and (iii) of Corollary 4.1.

(iv) of Corollary 4.1 can be proven similarly: We can show that the bidding strategy is increasing in N by showing that an increase in N leads to an increase in $(1+z)(N-1)$. As $(1+z)(N-1) = \frac{(1+\varepsilon)(N-1)+\gamma}{1+\varepsilon}$, this immediately follows. To show that the amount of overbidding is decreasing in N, we write the amount of overbidding as

$$b^{FPA}(v,z) - b^{FPA}(v,0) = \int_0^v \left(\frac{F(t)}{F(v)}\right)^{(N-1)} \left[1 - \left(\frac{F(t)}{F(v)}\right)^{z(N-1)}\right] dt$$

where the term in the square brackets is positive and does not depend on N, as $z(N-1) = \frac{\gamma}{1+\varepsilon}$. Hence, as $\frac{F(t)}{F(v)} < 1$ for any $t < v$ it follows that an increase in N leads to a decrease in the amount of overbidding. This concludes the proof of (iv) of Corollary 4.1. □

Proposition 4.2 *The symmetric equilibrium for bidders with social comparison concerns in second-price auctions is given by the bidding strategy*

$$b^{SPA}(v) = v + \int_v^1 \left(\frac{1-F(t)}{1-F(v)}\right)^{\frac{(1+\varepsilon)(N-1)+\gamma}{\gamma}} dt$$

Proof. This proof very closely follows the structure of the proof of Proposition 4.1 and, more specifically, follows the proof of Theorem 2 by Brandt et al. (2007, p. 1210). To prove Proposition 4.2, suppose that each bidder's utility is defined by (4.5). Bidder i's expected utility is then given by

$$\begin{aligned} E[U_i] =& (1+\varepsilon)Pr(W_i)\left(v_i - E[b(v_{(1)})|W_i]\right) \\ & - \frac{\gamma}{N-1}\left(Pr(\neg W_i)E[v_{(1)}|\neg W_i] - B(v_k)\right) \end{aligned}$$

Assuming that the bidding strategies $b(v_j)$ are strictly increasing and differentiable over the value space $[0,1]$ gives $Pr(W_i) = F(\widetilde{v})^{N-1}$, where $\widetilde{v}$ denotes the inverse function of $b_i(v_i)$. Following Brandt et al. (2007), the conditional expectations are given by the following expressions.

$$\begin{aligned} E[v_{(1)}|\neg W_i] &= \frac{1}{1-F(\widetilde{v})^{N-1}} \int_{\widetilde{v}}^{1} t(N-1)F(t)^{N-2}f(t)dt \\ E[b(v_{(1)})|W_i] &= \frac{1}{F(\widetilde{v})^{N-1}} \int_{b_i(0)}^{b_i(v_i)} t(N-1)F(\widetilde{v}(t))^{N-2}f(\widetilde{v}(t))\widetilde{v}'(t)dt \end{aligned}$$

From Brandt et al. (2007) we know that k's expected payment if she wins is given by the following expression.

$$\begin{aligned} B(v_k) =& (N-1)F(\widetilde{v})^{N-2}[1-F(\widetilde{v})]b_i(v_i) \\ & + (N-1)(N-2)\int_{b_i(v_i)}^{b_i(1)} t[1-F(\widetilde{v}(t))]F(\widetilde{v}(t))^{N-3}f(\widetilde{v}(t))\widetilde{v}'(t)dt \end{aligned}$$

Therefore, the expected utility of bidder i can be rewritten as follows.

$$\begin{aligned} E[U_i] =& (1+\varepsilon)\left(v_iF(\widetilde{v})^{N-1} - \int_{b_i(0)}^{b_i(v_i)} t(N-1)F(\widetilde{v}(t))^{N-2}f(\widetilde{v}(t))\widetilde{v}'(t)dt\right) \\ & - \gamma\left(\int_{\widetilde{v}}^{1} tF(t)^{N-2}f(t)dt - F(\widetilde{v})^{N-2}[1-F(\widetilde{v})]b_i(v_i)\right) \\ & + \gamma(N-2)\int_{b_i(v_i)}^{b_i(1)} t[1-F(\widetilde{v}(t))]F(\widetilde{v}(t))^{N-3}f(\widetilde{v}(t))\widetilde{v}'(t)dt \end{aligned} \tag{C.4}$$

Maximizing (C.4) with respect to $b_i(v_i)$ then yields the first-order condition

$$\begin{aligned} 0 = & (1+\varepsilon)(N-1)F(\widetilde{v})^{N-2}f(\widetilde{v})\widetilde{v}'(v_i - b_i(v_i)) + \gamma F(\widetilde{v})^{N-2}f(\widetilde{v})\widetilde{v}'\widetilde{v} \\ & + \gamma F(\widetilde{v})^{N-2}[1-F(\widetilde{v})] + \gamma(N-2)F(\widetilde{v})^{N-3}f(\widetilde{v})\widetilde{v}'b_i(v_i) \\ & - \gamma(N-1)F(\widetilde{v})^{N-2}f(\widetilde{v})\widetilde{v}'b_i(v_i) - \gamma(N-2)[1-F(\widetilde{v})]F(\widetilde{v})^{N-3}f(\widetilde{v})\widetilde{v}'b_i(v_i) \end{aligned} \tag{C.5}$$

Using the fact that $\widetilde{v}' = \frac{1}{b_i'(v_i)}$ and that in a symmetric equilibrium $b_i(v_i) = b(v_i)$, such that $\widetilde{v} = b^{-1}(b(v_i)) = v_i$, (C.5) can be rewritten as follows.

$$b'(v) = \frac{(1+\varepsilon)(N-1)+\gamma}{\gamma} \frac{f(v)}{[1-F(v)]}(b(v)-v) \tag{C.6}$$

It turns out that $b(0) = 0$ does not hold for the SPA. However, we can obtain a boundary condition by setting $v = 1$. By definition, $F(1) = 1$. It therefore follows that $b(1) = 1$. Multiplying by the integrating factor $[1-F(v)]^{\frac{(1+\varepsilon)(N-1)+\gamma}{\gamma}}$ yields the symmetric equilibrium bidding strategy.

$$b(v) = v + \int_v^1 \left(\frac{1-F(t)}{1-F(v)}\right)^{\frac{(1+\varepsilon)(N-1)+\gamma}{\gamma}} dt$$

Following Brandt et al. (2007), this expression is in fact a conditional expectation $b(v) = E[X|X > v]$, where the cumulative distribution function of X is given by $1-[1-F(x)]^{\frac{(1+\varepsilon)(N-1)+\gamma}{\gamma}}$. Notice that the bidding strategy is not defined for $\gamma = 0$. However, the correct equilibrium can directly be found by rewriting (C.6) as $b(v) = v + \frac{\gamma}{(1+\varepsilon)(N-1)+\gamma}\frac{[1-F(v)]}{f(v)}b'(v)$ and setting $\gamma = 0$. It follows that, like in the RNNE, $b(v) = v$.

As (C.6) is merely a necessary condition, we now proceed to prove that $b(v)$ is indeed a mutually best response. Suppose that all but bidder i use strategy $b(v)$. We prove that it is optimal for bidder i to also follow strategy $b(v)$. First, notice that $b(v)$ is continuous and strictly increasing:

$$b'(v) = \frac{(1+\varepsilon)(N-1)+\gamma}{\gamma} \frac{f(v)}{[1-F(v)]} \int_v^1 \left(\frac{1-F(t)}{1-F(v)}\right)^{\frac{(1+\varepsilon)(N-1)+\gamma}{\gamma}} dt > 0.$$

To check that $b(v)$ is indeed an equilibrium, use (C.6) to rewrite the first order condition in (C.5).

$$\begin{aligned} &\frac{f(\widetilde{v})}{[1-F(\widetilde{v})]}\left[(1+\varepsilon)(N-1)(v_i - b_i(v_i)) + \gamma(\widetilde{v} - b_i(v_i))\right] \\ &\qquad = \frac{f(v_i)}{[1-F(v_i)]}\left[(1+\varepsilon)(N-1)+\gamma\right](v_i - b(v_i)) \end{aligned}$$

It can easily be seen that the RHS and LHS are only equal, thereby satisfying the first-order condition, whenever $b_i(v_i) = b(v_i)$. This concludes the proof of Proposition 4.2. □

Corollary 4.2 *In second-price auctions with $N \geq 2$ bidders who have social comparison concerns, the following holds:*

- *If $\gamma = 0$, for any $\varepsilon \geq 0$ the symmetric equilibrium is given by the RNNE bidding strategy.*
- *If $\gamma > 0$, the following results hold:*
  - *(i) Overbidding occurs.*
  - *(ii) The bids and the amount of overbidding are increasing in upward comparison concerns, γ.*
  - *(iii) The bids and the amount of overbidding are decreasing in downward comparison concerns, ε.*
  - *(iv) The bids and the amount of overbidding are decreasing in N.*

Proof. To prove (i) of Corollary 4.2, let us compare the bidding strategy for bidders with and without social comparison concerns. For simplicity we reformulate the bidding strategy $b^{SPA}(v)$ as a function of z:

$$b^{SPA}(v, z) = v + \int_v^1 \left(\frac{1 - F(t)}{1 - F(v)} \right)^{\frac{1+z}{z}} dt$$

where $z = (\gamma)/((1 + \varepsilon)(N - 1))$. Notice that $z > 0$ for $\gamma > 0$, $\varepsilon \geq 0$ and $N \geq 2$. If $z \to 0$ the bidding strategy converges to the RNNE bidding strategy:

$$b^{SPA}(v, 0) = v$$

To prove that there is overbidding in the SPA, it therefore suffices to show that $\int_v^1 \left(\frac{1-F(t)}{1-F(v)} \right)^{\frac{1+z}{z}} dt$ is positive for $z > 0$. This follows immediately, as $0 \leq F(v) \leq 1$ and $1 - F(t) \geq 0$ for any $v \leq t \leq 1$. This concludes the proof of (i) of Corollary 4.2.

(ii), (iii) and (iv) of Corollary 4.2 can be proven similarly. That is, we only need to prove that the amount of overbidding is increasing in z. This is indeed the case, as for any $0 < z' < z''$ the following holds.

$$\left(\frac{1 - F(t)}{1 - F(v)} \right)^{\frac{1+z'}{z'}} = \left(\frac{1 - F(t)}{1 - F(v)} \right)^{\frac{z''-z'}{z'z''}} \left(\frac{1 - F(t)}{1 - F(v)} \right)^{\frac{1+z''}{z''}} \leq \left(\frac{1 - F(t)}{1 - F(v)} \right)^{\frac{1+z''}{z''}}$$

where the inequality follows from the fact that $\frac{1-F(t)}{1-F(v)} \leq 1$ for any $v \leq t \leq 1$ and from the fact that $\frac{z''-z'}{z'z''} > 0$. From the proof of Corollary 4.1 we already know that z is increasing in γ for $N \geq 2$, proving (ii) from Corollary 4.2, and decreasing in ε for $N \geq 2$ and $\gamma > 0$, proving (iii) from Corollary 4.2. To prove (iv) it suffices to show that z is decreasing in N for $\gamma > 0$:

$$\frac{\partial z}{\partial N} = -\frac{\gamma(1+\varepsilon)}{\left((1+\varepsilon)(N-1)\right)^2}$$

This concludes the proof of (iv) of Corollary 4.2. □

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Nederlandse samenvatting

Met de opkomst van het internet is het gebruik van veilingen sterk toegenomen. Tegenwoordig kan men vrijwel alles in een online veiling kopen: van elektronica en verzamelaarsobjecten in online marktplaatsen tot vakanties en concert tickets in gespecialiseerde online veilingsites. De economische literatuur, meer bepaald de speltheorie, analyseert veilingen als spellen van incomplete informatie. Daarbij ligt de focus vooral op klassieke veilingen, waarbij een monopolistische verkoper (bijvoorbeeld de overheid) een enkel goed aan een vast aantal rationele en winstmaximaliserende bieders (vaak bedrijven) verkoopt. Om online veilingen te bestuderen, moet de traditionele veilingliteratuur echter op een aantal gebieden worden aangepast.

Ten eerste zijn bieders in online veilingen vrijwel nooit winstmaximaliserende bedrijven die bieden voor goederen van hoge waarde, maar consumenten die bieden voor goederen van (relatief) lage waarde. Het is daarom mogelijk dat bieders niet aan de aannames uit de traditionele literatuur voldoen, maar bijvoorbeeld begrensd rationeel zijn of door emoties worden gedreven. Ten tweede bieden online veilingen de ideale setting om te experimenteren met nieuwe ontwerpopties—ze zijn immers relatief goedkoop om op te zetten, hebben de potentie om veel bieders aan te trekken en zijn niet gebonden aan plaats of tijd. Dit heeft geleid tot de ontwikkeling van nieuwe veilingformaten, zoals *Buy-It-Now*, oftewel Koop-Nu, veilingen. Ten derde wordt een enkel goed op het internet vaak op verschillende manieren verkocht. Zo kunnen consumenten een goed voor een vaste prijs kopen, maar kunnen ze ook kiezen uit talloze online veilingen. Dit betekent dat verkopers geen monopolisten zijn; ze opereren in een competitieve markt en strijden met elkaar om bieders. Het aantal bieders in een veiling staat daarom niet vast, maar is het resultaat van een proces van *endogenous entry*, oftewel endogene toetreding.

Dit proefschrift bestaat uit drie aparte studies die verschillende aspecten van de bovengenoemde correcties op de veronderstellingen van de traditionele veilingliteratuur onderzoeken. Hierbij worden zowel speltheorie als experimenten ingezet. Op deze manier draagt mijn onderzoek bij aan de recente vorderingen binnen de veilingtheorie en aan een verbetering van de relevantie van veilingtheorie voor online veilingen. In het onderstaande vat ik elke studie kort samen.

Het proefschrift begint met het bestuderen van endogene toetreding tot veilingen, en mededinging tussen veilingen. Hoofdstuk 2 laat middels een theoretisch model zien hoe homogene risico-averse bieders kiezen tussen een eerste-prijs of tweede-prijs veiling. Tevens wordt onderzocht wat deze keuzevrijheid betekent voor de verkopers bij het bepalen van het optimale veilingformaat. In een eerste stap onderzoek ik de keuze van de bieders tussen verschillende beschikbare veilingen. Ik toon aan dat er een uniek symmetrisch evenwicht bestaat, dat gemengd is, en waarvan de vorm afhangt van de mate waarin bieders absoluut risico-avers zijn. Als bieders kunnen kiezen tussen een eerste-prijs en tweede-prijs veiling, dan verdelen zij zich in gelijke mate over de twee veilingen indien zij risico-neutraal zijn of constante absolute risico-aversie vertonen. Echter, bieders zijn meer geneigd om mee te doen aan de tweede-prijs veiling indien zij dalende absolute risico-aversie vertonen, en meer geneigd om mee te doen aan de eerste-prijs veiling indien zij stijgende absolute risico-aversie vertonen. In een volgende stap analyseer ik de veilingkeuze van de verkopers. Omdat risico-averse bieders overbieden in eerste-prijs veilingen, maar niet in tweede-prijs veilingen, hebben concurrerende verkopers een dominante strategie om eerste-prijs veilingen te selecteren als bieders niet-dalende absolute risico-aversie vertonen. Echter, als bieders dalende absolute risico-aversie vertonen, dan bestaan er ook evenwichten waarbij verkopers tweede-prijs veilingen selecteren. Deze bevindingen zijn van rechtstreeks belang voor het ontwerp van online veilingen.

In hoofdstuk 3 wordt het onderzoek naar endogene toetreding voortgezet en worden ook niet-klassieke veilingen en niet-klassieke preferenties meegenomen. In een laboratoriumexperiment analyseer ik hoe consumenten kiezen tussen veilingen met of zonder Koop-Nu optie en kopen tegen een vaste prijs. Aan welk verkoopmechanisme geven consumenten de voorkeur? En kunnen deze voorkeuren verklaard worden door verschillen in verwachte opbrengsten, of worden ze ook beïnvloed door kenmerken van de consumenten zelf? Het experiment laat zien dat deelnemers minder vaak kiezen voor kopen tegen een vaste prijs dan voor de veilingen. Verder toon ik aan dat, voor een gegeven vaste of Koop-Nu prijs, deelnemers meer geneigd zijn om mee te doen aan een veiling wanneer de waarde die zij aan het goed hechten onder een bepaalde grenswaarde valt, en meer geneigd zijn om te kopen tegen een vaste prijs wanneer die waarde boven deze grenswaarde valt. Ongeduld heeft een negatieve impact op de waarschijnlijkheid dat een deelnemer voor een veiling kiest. Risico-aversie heeft daarentegen een positieve impact hierop. Daarnaast vind ik dat mannen meer geneigd zijn om voor een veiling te kiezen en dat vrouwen meer geneigd zijn om te kopen tegen een vaste prijs. Dit resultaat draagt bij aan de literatuur over geslachtsverschillen in competitieve voorkeuren.

In hoofdstuk 4, ten slotte, worden inzichten uit de gedragseconomie geïmporteerd om te analyseren hoe de aanwezigheid van sociale competitie het biedgedrag in veilingen beïnvloedt. Hiervoor maak ik gebruik van een model van *interdependent*, oftewel onderling afhankelijke, preferenties. In dit model vergelijken bieders hun eigen opbrengsten met de opbrengsten van een sociale referent of referentiegroep. Daarnaast veronderstel ik dat bieders een onderscheid maken tussen opwaartse en neerwaartse vergelijkingen: bieders voelen afgunst wanneer ze opwaarts vergelijken en voelen trots wanneer ze neerwaarts vergelijken. Ik toon aan dat het anticiperen van deze gevoelens leidt tot meer competitief biedgedrag in zowel eerste-prijs als tweede-prijs veilingen. In andere woorden, als bieders gericht zijn op sociale vergelijking leidt dit tot overbieden. Opvallend is dat dit resultaat gedreven wordt door het anticiperen van afgunst; het anticiperen van trots zwakt het effect van afgunst af. Dit impliceert dat verkopers vooral de mogelijkheid van sociale verliezen moeten benadrukken bij het ontwerpen van online veilingen. Tevens blijken tweede-prijs veilingen meer op te brengen dan eerste-prijs veilingen als bieders gericht zijn op sociale vergelijking.

Curriculum vitae

Joyce Delnoij (1989) was born in Heerlen and grew up in Mechelen, the Netherlands. She completed her high school education at Scholengemeenschap Sophianum in 2007. Joyce then moved to Utrecht to study at Utrecht University School of Economics (U.S.E.), where she received her Bachelor degree in 2010 and Research Master degree in 2012 (cum laude). During this time, she developed an interest in auctions and worked on a research project financed by the online auction company Emesa. This resulted in an experimental study, which was the topic of her Research Master thesis and proved the starting point of her PhD research. From 2012 to 2016, Joyce worked as a PhD candidate at U.S.E., where she completed this dissertation. As of June 2016, Joyce works as a senior editor at Economisch Statistische Berichten (ESB), the Dutch journal for policy economics. Her research interests cover game theory, behavioral economics and experimental economics.

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