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Operational efficiency of decentralized Internet auction mechanisms

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ABSTRACT

The recent consumer-to-consumer (C2C) Internet auction boom at eBay, Yahoo, Amazon, and other sites has added new theoretical challenges to the science of auctions. This paper uses experiments with economically-motivated human subjects to measure the operational efficiency of decentralized Internet auction mechanisms as they compare to centralized double auction mechanisms. Subjects are recruited randomly from the undergraduate population of a large urban university to be buyers or sellers in a simulated trading environment. They are randomly assigned costs and values for 10 units of a virtual product. During the experiment subjects trade these units through computer terminals in auctions similar to those held on eBay and generate profits, which subjects receive at the end of the experiment. The paper uses data from this experiment and previous laboratory experiments to compare operational efficiency and convergence pattern of prices to equilibrium levels in continuous double auctions versus online Internet auctions based on two variables: auction size and time. Experimental results suggest that, because of their decentralized nature, Internet auctions require a few more participants and more time to achieve operational efficiency levels than centralized markets which use continuous double auction mechanisms.

1. Introduction

Over the last decade online consumer-to-consumer (C2C) auctions have had an enormous impact on business the world over. Yet we still know very little about how efficiently goods are being exchanged online and whether and how the efficiency of the online trading process could be improved. This is in parallel with the relative lack of studies that reliably measure efficiency even in traditional offline auctions. At the same time efficiency is often one of the major criteria when an agency is choosing between possible alternative mechanisms for selling various property rights or other products (e.g. see Cramton 1998; Cox et al. 2002).

Tracking the efficiency of an auction mechanism has also important practical significance for online auction managers (Gallien and Gupta 2007; Kauffman et al., in press; Caldentey and Vulcano 2007). On the web the major source of revenue for auction marketplaces is the commissions and listing fees. Commissions are usually a percentage of the transaction price. In order to maximize revenue, online auction managers should maximize transaction prices and transaction volume. However, if the process of raising prices also results in much lower buyer surplus, then many buyers would be turned away from the auction website to other alternatives. In order to improve profitability without hurting buyers, online auction managers can implement policies that increase transaction prices and auction efficiency at the same time and at least at approximately the same rate. This would guarantee that buyers are not hurt in the process of increasing auction website revenue. This is why auction managers should be concerned about efficiency when they make changes to auction rules that might influence auction prices and performance (Wenyan and Bolivar 2008).

There are two different definitions of market efficiency that have been used to assess how well auctions in general and Internet auctions in particular perform. The first type of market efficiency is known as *operational* (*or allocative*) *efficiency*. This efficiency is defined as a percentage of the maximum possible surplus extracted by a market institution while demand and supply are being matched (see Parsons et al. 2006). This idea of efficiency works well for *final products* – or products that have well-defined production costs that the sellers incur and also have some intrinsic usually heterogeneous values to the buyers (see Milgrom and Weber 1982; also Krishna 2002, and Klemperer 2004). Both buyers and sellers need to perform only one transaction in order to enjoy gains from trade. The difference between the transaction price and the production and other costs is the seller surplus, and the difference between the buyer's value and the transaction price is the buyer surplus. The sum of these two surpluses is the total surplus, and operational efficiency is the ratio between the total realized surplus and the total possible surplus. This idea of efficiency allows establishing efficiency baselines, ranking different auction mechanisms, and makes possible the estimation of the effect of a change in a

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certain market variable that is under a market designer's control. This type of efficiency is hard to estimate using market data except in some limited circumstances (see Kang and Puller 2008; Hortacsu 2002; Gopal et al. 2007) because much of the information about real costs and values is never fully revealed by market participants. An easy way to see how operational efficiency is impacted by market variables is through laboratory experiments with economically-motivated human subjects (Smith 2002, 2003) in which values and costs are directly induced by the experimenter.

The second idea of efficiency, which we call *informational efficiency*, exists when there is no potential for arbitrage in the market. This idea of efficiency is usually used to assess how well financial markets perform (see Fama 1991). The idea is useful for financial markets because financial paper does not have intrinsic value, that is, in order to realize profits, one has to buy a financial product and then sell it later. Thus the value of a financial product depends on the future expectations of all market participants. Market participants' values for products similar to financial paper are common or correlated. Informational efficiency is thus quite relevant in financial and other markets where market participants are expected to re-trade an item before they can realize a profit. Financial economists have developed methods to detect if a market is informationally efficient by using past price data (see Davis 2008 for a review). There have already been several studies that have used this methodology to find that current C2C auctions are not informationally efficient (see Kauffman et al., in press).

What are the factors that impact market efficiency? Classical economic theory suggests that one of the most important variables that can affect efficiency is the number of participants in a market mechanism (see MacKenzie et al. 2007). This is also termed *market size*. More recently modern auction theory has devoted much attention also to the importance of the market mechanism which is being used to match supply and demand (see Krishna 2002; Klemperer 2004; Smith 2003). We know the structure and rules of currently available Internet auction mechanisms. However, we do not know exactly how inefficient the auctions are and how their efficiency is impacted by an increase in the number of auction participants. This paper is an initial attempt to fill this gap in current research. In the new context of Internet auction mechanisms, this study asks the following research questions:

- How is the operational efficiency of online auctions influenced by auction size?
- How is the relationship between auction size and efficiency different in decentralized Internet auction mechanisms versus more centralized market mechanisms like *continuous double auctions*?
- How do prices converge over time to competitive levels in more decentralized mechanisms like Internet auction mechanisms versus centralized market mechanisms like continuous double auctions?

To address these questions the paper uses an exploratory laboratory study with economically-motivated human subjects. The experiment presented here was conducted in the summer of 2001 and is among the first laboratory experiments involving human subjects that tries to simulate the economic environment surrounding online auction mechanisms for final goods. The main experimental finding reported here is that Internet auctions need more than seven buyer visits per auction in order for auction prices to reach competitive levels. It also turns out that Internet auction mechanisms require more time than centralized markets to achieve high efficiency levels.

This paper makes several contributions to theory and practice. First, it shows that a basic principle from economic theory about the relationship between market size and market efficiency applies to Internet auctions. Second, it extends previous experimental work in auctions to show that Internet auction mechanisms are different in their convergence properties from centralized double-auction mechanisms. Third, the paper can serve as a guideline to online auction designers as to how operational efficiency could be measured in the laboratory and describes a method to establish an efficiency baseline, change certain auction variables and estimate the effect of that change on the operational efficiency of the auction mechanism being tested. Lastly, the paper uses the reported research findings to suggest ways in which operational efficiency of online auctions could be improved.

The article is organized in the following way: Section 2 provides an overview of previous research related to C2C Internet auctions and describes in detail the main differences between the centralized commodity markets experimentally tested by Smith and some of the most popular current C2C Internet auctions like eBay. Section 3 discusses the methodology and Section 4 describes the main features of the experimental design. Section 5 reports the experimental results, Section 6 discusses their implications. Section 7 provides a summary of the limitations and the conclusion.

2. Theory

As stated by Kannan and Kopalle (2001), dynamic pricing on the Internet has become very popular over the last decade. Consumers and businesses are seemingly embracing various auction formats as legitimate ways to exchange goods and services online. This trend has been driven by the substantial decrease in search costs (Bakos 1997) and by the positive attitude of consumers towards using computers and technology to support C2C transactions (Stafford and Stern 2002). Electronic auctions of various kinds have also been used extensively in online B2B market settings as part of traditional supply chains and supply networks (Anandalingam et al. 2005; Pinker et al. 2003). So far efficiency and prices in online auctions have been explored with the help of two scientific methods: data analysis of naturally occurring Internet auctions, and data analysis of results from field experiments. We next review the results from both of these approaches.

2.1. Analyzing price data from naturally occurring Internet auctions and from field experiments

Lucking-Reiley et al. (2007) and Ariely and Simonson (2003) are one of the first studies to investigate the behavior of prices in online auctions using price data from eBay. The econometric models presented in these studies are useful because they show important relationship between various observable auction variables, however, they do not report results specifically related to the efficiency of the auction mechanisms being studied. We later use these models to establish similarity in behavior between the laboratory and the real world, and to illustrate the results of the paper. Roth and Ockenfels (2002) is an attempt to analyze an important phenomenon in online auctions with hard deadlines: *sniping*. Sniping occurs when buyers wait until the very end of the auction before they submit bids. They claim that sniping would decreases efficiency but they do not measure efficiency itself. This study is also useful because the theoretical model and econometric analysis presented there could serve again as way to establish similarity between subject behavior in the laboratory and buyer behavior online. Most of the studies based on price data do not investigate efficiency directly. The same observation pertains to studies that use data from field experiments (e.g. Durham et al. 2004; Ba and Pavlou 2002; Lucking-Reiley 1999).

Just recently Gopal et al. (2007) argue that the fundamental principles driving financial markets and online markets are very