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Price formation and its dynamics in online auctions

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Abstract

This research uses functional data modeling to study the price formation process in online auctions. It conceptualizes the price *evolution* and its first and second derivatives (velocity and acceleration respectively) as the primary objects of interest. Together these three functional objects permit us to talk about the *dynamics* of an auction, and how the influence of different factors vary throughout the auction. For instance, we find that the incremental impact of an additional bidder's arrival on the rate of price increase is smaller towards the end of the auction. Our analysis suggests that "stakes" do matter and that the rate of price increase is faster for more expensive items, especially at the start and the end of an auction. We observe that higher seller ratings (which correlate with experience) positively influence the price dynamics, but the effect is weaker in auctions with longer durations. Interestingly, we find that the price level is negatively related to auction duration when the seller has low rating whereas in auctions with high-rated sellers longer auctions achieve higher price levels throughout the auction, and especially at the start and end. Our methodological contributions include the introduction of functional data analysis as a useful toolkit for exploring the structural characteristics of electronic markets.

Keywords: Functional regression analysis; Data smoothing; eBay; Online auction; Auction dynamics; Electronic commerce

1. Introduction and background

Auctions have long served as operationally simple mechanisms that coordinate privately held information quickly and accurately to achieve efficient exchange. In doing so, they play a critical role in informing us about the underlying price formation process. Nowhere is this more evident than on eBay, perhaps the world's largest online auction house, where over to a billion items were listed for sale in 2006. The focus of this research is to shed new light on the *dynamics* of the price formation process of online auctions on eBay. We depart from extant online auction research by conceptualizing the auction price *evolution* and its first and second derivatives (signifying price velocity and acceleration respectively) as our primary objects of interest. By price velocity we mean the speed of the price increase and

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similarly by price acceleration we mean the rate at which this speed changes[2].

There is a growing amount of evidence that dynamics matter in the online environment and that the study thereof can have significant benefits for all parties involved in an online transaction. [12] study eBay auctions and find that price dynamics can be very heterogeneous, even for auctions of the same product. Similarly, [20] study the heterogeneity of dynamics in auctions for modern Indian art. [25] use price dynamics to create real-time forecasting models for ongoing auctions and find that these dynamic models significantly outperform models that use only static information. [11] develop visualizations for the price formation process and its dynamics to study the effect of concurrency among online auctions. Dynamics also matter outside the auction environment. [23] for instance investigate the evolution of open source software projects using dynamic models. An overview of recent advances in dynamic modeling for electronic markets can be found in [13].

Commencing primarily after the seminal piece by [24], the extensive auction theory literature has limited its attention to explanatory power of the static auction price measure. Using online auction price information, researchers have investigated the revenue equivalence across auction formats [16], the impact of mechanism design choices made by sellers [2], the determinants of price [17], consumer surplus levels [6] and the magnitude of reputation premiums (see [8,1]) , ba:pavl:2002. The interested reader is referred to a recent exhaustive survey of online auction research by [3]. In this paper, we emphasize the importance of understanding and exploring the means to the end of getting to the price, namely the price formation process.

We achieve our goal by leveraging some of the most recent statistical methodological advances in functional data modeling that allow for input and/or output variables to be functional objects. The functional data modeling toolkit that we present permits us to study determinants of an auction's price formation by estimating time varying functional relationships (as opposed to scalar betas) that relate the auction's price formation process to its explanatory factors. Thus, we obtain insights into how the magnitude and significance of an effect, (e.g., the seller's rating), varies as an auction progresses.

Based on prior research, we limit our attention to five sets of explanatory variables and their interactions. To the best of our knowledge, prior applications of functional data modeling with a functional response have not studied interactions between explanatory variables. Yet, auction theory [3,6] informs us that such interactions do play a role in influencing an auction's closing price, and hence can be expected to influence the price formation. Our five sets of explanatory variables include product characteristics, and seller and bidder characteristics as measured by their eBay ratings. They also include seller mechanism design choices, namely the starting price level, the auction duration and the usage of a hidden reserve. Interestingly, our data (described further in Section 4) consist of auctions in three major currencies, namely US Dollar, Great Britain Pound and the Euro. This allows us to examine differences between the US and European markets as well as product item category effects. We elaborate on each of these in Section 3.

We believe that understanding the drivers of an auction's price formation, its velocity and its acceleration is a critical first step towards being able to pursue dynamic mechanism design in the online auction environment. [5] point out that a largely unconsidered aspect of the online auction environment is how the technologically-enhanced information gathering and processing capabilities might be used to perform real-time auction calibration. For instance, given that acceleration leads to change in velocity, which in our context subsequently impacts the price evolution, it is worth considering the impact that *dynamic bid increments*, designed to nudge a given auction towards a desirable trajectory, would have on an auction's price evolution and on bidding behavior. In this research, we attempt to begin this dialogue by developing a methodological toolset that allows us to understand what factors influence the dynamics of online auctions' price formation.

In the next Section we introduce the methodological toolkit necessary for investigating the dynamic price formation process. This toolkit relies heavily on ideas from what is often referred to as "Functional Data Analysis".

[2] The ability to measure velocity and acceleration permts us to formalize novel concepts such as an auction's *energy*. In physics, energy (or more precisely kinetic energy) is referred to as "the capacity to do work." That is, kinetic energy E is defined as $E=M\times v^2/2$, where M refers to "mass" and v referes to "velocity." Note that velocity is function of distance and time: if the velocity is higher, then we can pass through the same distance in faster time. In the auctin cntext we are intereseted in auction's capacity to mve the price. Items of higher value have more mass, and the price velocity measures how fast the auction can move the price of item a certain distance.