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# Feedback reviews and bidding in online auctions: An integrated hedonic regression and fuzzy logic expert system approach

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ABSTRACT

In online auctions, user-generated feedback reviews provide first-hand information on the trustworthiness of transaction partners to the community. To examine how the feedback reviews are taken into account of the buyers' bidding decisions and thus affect the final winning price of an auction, we thoroughly examine how buyers mentally interpret the seller's reviews and adjust the bids accordingly. With ample bidding results data from a popular auction website eBay.com, this paper adopts an integrated approach of Fuzzy Logic Expert System (FLES) model and a statistical hedonic regression model to examine the research question. In particular, we use the hedonic regression approach to select key variables, which are then entered into a FLES analysis to generate knowledge base regarding the relationships between variables such as item characteristics, auction characteristics and review scores, and the final winning price. This integrated approach combines the advantages of both methods, and also overcomes their own limitations. In addition, we also present the insights gained from bidding behaviors utilizing each of the approaches.



## 1. Introduction

In online auctions, user-generated feedback reviews provide first-hand information on the trustworthiness of transaction partners to the community. The literature on consumers' bidding decisions in online auctions has mainly focused on the buyers' trust building based on the feedback system (Ba and Pavlou [3], McDonald and Slawson [20], Melnik and Alm [21], Bajari and Hortacsu [5], Dewan and Hsu [8], Houser and Wooders [13], and Resnick et al. [27], Zhang [38], and Lucking-Reiley et al. [18]). Most of these studies adopted a *hedonic regression model*. According to hedonic theory, each good is considered as a set of characteristics and the price of the good is explained by the consumers' preferences for all those characteristics (Rosen [28], Epple [9] and Bajari and Benkard [4]). As a result, hedonic regression models are empirical summaries of the relationship between the prices and the characteristics of goods sold. In the research setting of online auctions, the constituent characteristics include detailed product information (name, brand, color, degree of use, etc.), auction settings (starting and ending time, minimum bid, shipping price, etc.), seller and buyer's background (user ID, location, member since, etc.). Hence a hedonic regression model enables us to examine the impact of each variable on the bidding outcome.

Hedonic regression model can provide direct connection between each individual variable to the winning price. However, due to the limitations of this approach, it cannot offer causal and combinatorial explanations to the relationships between the auction parameters and outcomes. Since there are significant amount of variables appearing in each auction, a buyer usually does not decide the bid based on each variable independently, but consider some or all the variables in interactive and complicated ways. To gain additional insights on this problem, it is necessary to explore different methods to systematically evaluate consumer online behaviors.

To overcome the limitation mentioned above, we choose to use a *Fuzzy Logic Expert System* (*FLES*) auto rule-generation technique. Fuzzy logic (FL) theory was introduced by Latfeh Zadeh [35–37] and developed over time with the stated goal to broaden the ability of decision analysis to handle imprecise sets by leveraging the role of natural language and probability theory. FL can be found everywhere today; from cars, automatic transmissions, photo cameras to automatic traffic controller systems. One of the reasons for such a proliferation of FL is its ease of use combined with its robustness in solving difficult problems. To that end it is important to understand how this can be applied to online auctions.

When dealing with human subjects, one of the difficulties is the complexity of human decision making. One of the advantages of FL is its use of natural language structure to convey complex decision making criteria in an easy to understand form. Further analysis of the natural language patterns (rules) can shed light into shopper's behavior so as to provide better insight into what drives online interactions between buyers and sellers on eBay. With this approach it is possible to answer the problem posed by Ha et al. [11] on the possibility of having a natural language option to examine complex system of patterns. This in turn will enable marketers to view "how individual predictor variables will

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influence the target and how they would interact". In this regard we will use a similar technique as Wu and Wu [34] when they used FL to provide e-commerce product recommendations from a trustworthy vendor by utilizing the user's own preferences. Kent [16] also adopted both the regression and FLES approaches to study the causal relationships between multiple variables and a dependent variable. Other studies in the engineering and medical fields (Andres et al. [2], Hasiloglu et al. [12], Kwok et al. [17]) have concentrated on a straight accuracy comparison between FLES and regression.

To examine how the feedback reviews are taken into account of the buyers' bidding decisions and thus affect the final winning price of an auction, we examine how buyers mentally interpret the seller's reviews and adjust the bids accordingly. It is the goal of this paper to present insights gathered from the use of both the hedonic regression model and the FLES model. The hedonic regression model can reveal the *independent* contribution of each individual variable to the prediction of the winning price after controlling all the other variables. On the other hand, the contribution of FLES is to reveal the detailed *inter-relationship* among the independent variables and how these variables together affect the bidding behaviors on eBay. We use the hedonic regression approach to select key variables, which are then entered into a FLES analysis to generate knowledge base regarding the relationships between variables such as item characteristics, auction characteristics and review scores, and the final winning price. This integrated approach combines the advantages of both methods, and also overcomes their own limitations.

This paper aims to present a better understanding of how customers on eBay adjust their bids according to reviews, through the use of an integrated approach of two models. We present the theories and compare the advantages and disadvantages of each method in Section 2. Variables and data are described in Section 3. Detailed models and results are presented in Section 4. Additionally, practical implications of this study will be presented in Section 5. Section 6 concludes the paper.

## 2. Theoretical background

### 2.1. The strengths and limitations of the hedonic regression approach

Regression analysis focuses on the relationship between a dependent variable and one or more independent variables based on a functional specification. Regression analysis estimates the change of the dependent variable when any one of the independent variables is varied, while the other independent variables are held *fixed*. Thus, regression analysis can measure not only the *impact* of an independent variable on the dependent variable, but also the *extent* of the impact.

However, the regression approach has many limitations suggested by the literature (Ragin [26], Schrodt [30], Kent [16], Ahmed et al. [1]):

First, regression analysis assumes that variables have *normal* distributions. Non-normally distributed variables (highly skewed variables, platykurtic or leptokurtic distributions or variables with substantial outliers) can distort relationships and significance tests. This assumption limits the application of this method to data samples with multi-modal or categorical types of variables.

Second, regression analysis assumes that *each* independent variable makes a fixed unit impact on the dependent variable, ignoring the inter-relationships between variables or the possibility that when some conditions are *combined*, the impact of an individual independent variable may be very different.

Third, the assumptions of additivity and linearity in regression analysis make possible the extrapolated results beyond the *range* of observed values.

Fourth, regression analysis ignores asymmetrical relationships between inputs and outcomes and the combinatorial effects of input factors. Thus it fails to distinguish necessary and sufficient *causes*.

### 2.2. The FLES approach

Fuzzy Logic (FL) is a superset of conventional Boolean logic that has been extended to handle the concept of partial truth. That is, it can handle values between such concepts of Boolean logics of completely true (1) and completely false (0). Classically, this is referred to as the law of the excluded middle and was originally developed as part of Aristotelian logic. FL was introduced in the 1960s as a means to model the uncertainty of natural language. A Fuzzy Logic Expert System (FLES) is a system that uses a collection of fuzzy membership functions and rules, instead of Boolean logic, to reason about data (Kent [16]). The rules in a FLES usually have an 'If–Then' form and can be applied to the dataset, or the methodology can auto-generate rules from the given dataset which can be used for estimation (Garratt and Hodgkinson [10]). The set of rules in a FLES, known as the rule base or knowledge base, are formulated as combinations of conditions leading to an outcome.

This approach offers several unique advantages over hedonic regression. First, FLES can be translated into a set of simple rules which can be analyzed in a more user-friendly form (Ha et al. [11]). Secondly, an advantage of using FLES is the ability to use Fuzzy Set Theory with cluster analysis while creating pattern sets and boundaries (Wen et al. [33]). Thirdly, unlike regression models, results of FLES are bounded by actual dataset feasibility limits, thus it is not possible to achieve results outside upper or lower bounds of the stated problem set. For a more detailed discussion of this boundary problem as applied to market definition, see Hrushka [14].

On the other hand, FLES cannot assess the relative contribution of potential conditions to an outcome and therefore it cannot pick out the key variables. In our research problem of eBay auctions, the winning bid price depends on as many as 16 factors and each factor is recorded as low, medium or high. That can result in a maximum of $3^{16}$ rules. If we can remove some insignificant variables, it will significantly reduce the complexity and improve clarity of the knowledge base. Kent [16] suggests that regression models can "*be used in a first stage to select key variables which are then entered into a fuzzy logic model to analyze the asymmetric relationships and alternative ways to an outcome*".

Given these strengths and weakness of the two approaches (summarized in Table 1), we adopt an approach of using a hedonic regression model to select variables that have significant importance to the winning price, and then applying the selected variables to FLES to derive the knowledge base.

**Table 1**
The strengths and weaknesses of the regression and FLES methods.

| Regression | FLES |
|---|---|
| Can measure the extent to which each condition is correlated with the outcome variable | Ignore assessment of the relative contribution of potential conditions to an outcome |
| Assume each independent variable makes a fixed unit of contribution to an outcome. | Study the configuration of conditions relating to an outcome. When some conditions are combined, the contribution of individual factors may be very different, even reversed. |
| Do not allow for the possibility that outcomes maybe achieved in more than one way | |
| Focus on distribution of variables. Cannot handle categorical data | Ignore variation and distribution in each variable. Can handle categorical data |
| Linear and additive relationships may obtain extrapolated values out of the practical range | Will not go beyond range |
| Symmetrical relationships between dependent and independent variables. | Can detect asymmetrical relations: focus on conditions that may be sufficient, necessary or both. |
| Cannot distinguish between relationships that are sufficient but not necessary or necessary but not sufficient. | |
| Results are very specification dependent and unstable | Results are specification independent |