

Sentiment in Online Car Auctions

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Motivation

- ▶ E-commerce: Ebay, Amazon, Facebook Marketplace, and others
 - ▶ Data accessibility
 - ▶ How does the online nature of the market affect how it operates?
 - ▶ Adverse selection

Motivation

- ▶ Lewis (2011) – “Asymmetric Information, Adverse Selection and Online Disclosure: The Case of eBay Motors”
 - ▶ “Institutional features” – photos, text, etc. allows sellers to reveal private information
 - ▶ Adverse selection effects disappear
- ▶ Comments, product reviews are also similar institutional features
 - ▶ Sentiment

Motivation

Sentiment in economics:

- ▶ Angelitos and La'O (2013)
- ▶ Baker and Wurgler (2007)
- ▶ Yen et al. (2021) and Xu and Hsu (2022)

Motivation

In this paper...

- ▶ Auction rather than asset market
- ▶ Sentiments are expressed directly on the marketplace
- ▶ Sentiments are accessible to all agents of the market

Motivation

Question: Does sentiment in the context of an auction affect its final price?

Data

- ▶ carsandbids.com
 - ▶ Online car auction website
 - ▶ English auctions
 - ▶ Model years 1980 and up
 - ▶ Over 10,000 cars sold

Figure 1: carsandbids.com homepage.

cars&bids

Auctions

Sell a Car

What's Cars & Bids?

Search for cars (ex. BMW, Audi, Ford)

Sign Up

Auctions

Years ▾

Transmission ▾

Body Style ▾

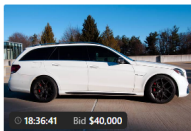
Ending soon

Newly listed

No reserve

Lowest mileage

Closest to me



⌚ 18:36:41 Bid \$40,000

2015 Mercedes-Benz E63 S AMG Wagon

577-hp Twin-Turbo V8, AWD, Diamond White Metallic, Mostly Unmodified
West Bloomfield, MI 48323



⌚ 18:43:41 Bid \$7,400

1994 Ford Bronco XLT 4x4

NO RESERVE 5.8-Liter V8 Power, 4WD, Tobago Green Clearcoat, Some Modifications
Yorba Linda, CA 92886



⌚ 18:50:41 Bid \$50,000

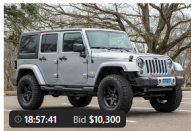
2022 Chevrolet Camaro ZL1 Coupe

650-hp Supercharged V8, Magnetic Ride Control, Shadow Gray Metallic
Irvine, CA 92612



Cars & Bids is the best marketplace for modern enthusiast cars.

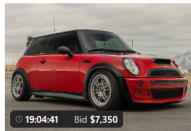
More about us



⌚ 18:57:41 Bid \$10,300

2013 Jeep Wrangler Unlimited Sahara 4x4

6-Speed Manual, V6 Power, 4WD, Some Modifications
Stratford, CT 06614



⌚ 19:04:41 Bid \$7,350

2005 Mini Cooper S

NO RESERVE 6-Speed Manual, Chili Red, Extensive Performance Modifications
Herriman, UT 84096



⌚ 19:11:41 Bid \$35,250

2013 Lexus LX 570

~47,800 Miles, 4WD, 1 Owner, Highly Equipped, Florida-Owned
Orlando, FL 32809

New Listings

**2017 BMW Alpina B7**

Twin-Turbo V8 Power, AWD, Highly Optioned, Unmodified

- Massaging front seats
 - Bowers & Wilkins sound system
 - Night vision
- La Jolla, CA 92037

Figure 2: Basic vehicle information.

cars & bids

Auctions

Sell a Car

What's Cars & Bids?

Search for cars (ex. BMW, Audi, Ford)

Sign Up

Time Left 18:34:44

High Bid \$40,000

Bids 10

Comments 34

Place Bid



Ending March 22nd at 1:30 PM EDT

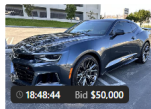
| | | | |
|--------------|--|----------------|------------------------|
| Make | Mercedes-Benz | Engine | 5.5L Turbocharged V8 |
| Model | E63 AMG ☆ | Drivetrain | 4WD/AWD |
| Mileage | 84,300 | Transmission | Automatic (7-Speed) |
| VIN | WDDHH7G81F8119478 | Body Style | Wagon |
| Title Status | Clean (MI) | Exterior Color | Diamond White Metallic |
| Location | West Bloomfield, MI 48323 | Interior Color | Black |
| Seller | avfolk Contact | Seller Type | Private Party |

**Doug's Take**

We love the Mercedes-Benz E63 AMG Wagon on Cars & Bids – it boasts a powerful V8 engine, it touts a luxurious interior, and it's an amazing combination of performance and practicality. This 577-horsepower, S212-generation E63 AMG Wagon is finished in gorgeous Diamond White Metallic, and it boasts the AMG Exterior Carbon Fiber Package, dynamic LED headlights, a Harman/Kardon sound system, and lots of driver assist features. Plus, this E63 hasn't been significantly modified – and it comes with a clean, accident-free Carfax report, for added peace of mind.

Ending soon**1994 Ford Bronco XLT 4x4**

NO RESERVE 5.8-Liter V8 Power, 4WD, Tobago Green Clearcoat. Some Modifications
Yorba Linda, CA 92886

**2022 Chevrolet Camaro ZL1 Coupe**

650-hp Supercharged V8, Magnetic Ride Control, Shadow Gray Metallic
Irvine, CA 92612

Figure 3: Comments & Bids section.

Comments & Bids
Newest
Most Upvoted
Seller Comments
Bid History

Add a Comment...

PlaneJaneCars

↑ 2 just now

Bid \$12,000
↑ 1

popaled

↑ 239 just now

Do we have a counter @planejanecars

↑ 0
Reply
Flag as inappropriate

cornack

↑ 50 just now

Bid \$11,500
↑ 3

popaled

↑ 239 just now

Will there be a war

↑ 0
Reply
Flag as inappropriate

PlaneJaneCars

↑ 2 just now

Bid \$11,300
↑ 1

Data

- ▶ Total data scraped:
 - ▶ 8,405 auctions
 - ▶ Reduced to 6,942 after removing make-models with few observations
 - ▶ Auctions ending April 26, 2021 to January 6, 2023

Table 1: Summary Statistics

| Variables | Mean | SD | Min | Max | N |
|------------------------|-----------|-----------|-------|---------|-------|
| Price | 30,815.89 | 30,121.88 | 2,950 | 405,911 | 6,942 |
| Sentiment score | 0.62 | 0.11 | 0 | 1 | 6,942 |
| Number bids | 28.32 | 13.50 | 1 | 139 | 6,942 |
| Number bidders | 12.41 | 4.57 | 1 | 33 | 6,942 |
| Number comments | 41.29 | 26.25 | 1 | 381 | 6,942 |
| Mileage | 76,421.89 | 56,092.31 | 5 | 336,400 | 6,942 |
| Number highlights | 5.21 | 0.86 | 3 | 8 | 6,942 |
| Number equipment | 11.96 | 4.21 | 1 | 35 | 6,942 |
| Number modifications | 5.77 | 8.62 | 0 | 118 | 6,942 |
| Number known flaws | 6.45 | 3.84 | 0 | 28 | 6,942 |
| Number service history | 3.68 | 3.65 | 0 | 40 | 6,942 |
| Number other items | 4.23 | 2.18 | 0 | 24 | 6,942 |
| Number owner history | 1.00 | 0.07 | 0 | 1 | 6,942 |
| Number videos | 2.92 | 2.13 | 0 | 22 | 6,942 |
| Number views | 10,590.55 | 5,792.04 | 2,912 | 96,557 | 6,942 |
| Number photos | 117.98 | 47.86 | 37 | 443 | 6,942 |

Methodology: Overview

1. Define and create a sentiment score for each auction
2. Define a linear model to explain price as a function of the other variables
 - ▶ Regress $\ln(\text{Price})$ on $\ln(\text{Sentiment score})$, other covariates, and controls

$$\ln y_t = \beta \times \ln(\text{Sentiment Score}_t) + \lambda x_t + \alpha \gamma_t + \varepsilon_t$$

Methodology: Sentiment Analyzer

- ▶ Optimally:
 - ▶ Random subset of comments would be used to create training dataset
 - ▶ Sentiment analyzer would be trained using this dataset
 - ▶ Benefit: best performance
 - ▶ Downside: long process, time and resource constraints
- ▶ Alternative:
 - ▶ Use preexisting, “off-the-shelf” sentiment analysis model
 - ▶ “Twitter-roBERTa”
 - ▶ Trained on 124M tweets from January 2018 to December 2021

Methodology: Sentiment Score

- Mean:

$$sentimentscore_n = \frac{\sum_i sentimentscore_{n,i}}{I_n}$$

Where

- $sentimentscore_n$ is the overall sentiment score for an auction n
- $sentimentscore_{n,i}$ is the sentiment score for a message i in an auction n
- I is the total number of messages in an auction n
- All sentiment scores min-max scaled to $[0, 1]$

Methodology: Regression Analysis

$$\ln y_t = \beta \times \ln(\text{Sentiment Score}_t) + \lambda x_t + \alpha \gamma_t + \varepsilon_t$$

Where

- ▶ y_t is the price or ending bid of an auction t
- ▶ Sentiment score $_t$ is the sentiment score of auction t
- ▶ x_t is a vector of other covariates (next slide)
- ▶ γ_t is a vector of control variables which contains the year as well as dummy variables for the make, model, and color of vehicle in order to control for the intrinsic value of the vehicle of auction t
- ▶ ε_t represents the idiosyncratic preferences of the highest bidder of an auction t which may affect their bid

Table 2: Variables in vector x

| Variables | Type | Description |
|------------------------|------------|---|
| Number bids | discrete | Number of bids of the auction. |
| Number bidders | discrete | Number of bidders in the auction. |
| Number comments | discrete | Number of comments in the “Comments & Bids” section. |
| Mileage | continuous | Milage of vehicle on auction. |
| Private seller | binary | 1 if seller of vehicle is a private seller, i.e. not a dealership. 0 otherwise. |
| Number highlights | discrete | Number of highlights listed. |
| Number equipment | discrete | Number of equipment listed. |
| Number modifications | discrete | Number of modifications listed. |
| Number known flaws | discrete | Number of known flaws listed. |
| Number service history | discrete | Number of service history listed. |
| Number other items | discrete | Number of other items listed. |
| Number owner history | discrete | Number of owner history listed. |
| Number videos | discrete | Number of videos on auction page. |
| Title status | binary | 1 if vehicle has a clean title. 0 otherwise. |
| Number views | discrete | Number of times auction was viewed. |
| Number photos | discrete | Number of photos of vehicle. |

Methodology: Specification

$$\ln y_t = \beta \times \ln(\text{Sentiment Score}_t) + \lambda x_t + \alpha \gamma_t + \varepsilon_t \quad (1)$$

versus

$$y_t = \beta \times (\text{Sentiment Score}_t) + \lambda x_t + \alpha \gamma_t + \varepsilon_t \quad (2)$$

- ▶ (2) presumes that covariates have a dollar effect on price
 - ▶ Does not change depending on the price of vehicle

however...

- ▶ A dollar effect is higher for a lower priced vehicle than higher priced vehicle
- ▶ Intuitively, this should not necessarily be the case
- ▶ (1) with log allows for *percentage* effect on price per 1% change in β

Results

Table 3: OLS Estimation Results

| | | | |
|---------------------|----------------------|--|----------------------|
| | (1) | Milage | -0.000*** (0.000) |
| | ln(Price) | | |
| ln(Sentiment score) | 0.199*** (0.019) | Number modifications | 0.004*** (0.001) |
| Reserve | 0.170*** (0.010) | Number known flaws | -0.026*** (0.001) |
| Number bids | 0.007*** (0.000) | Number views | 0.000*** (0.000) |
| Number bidders | -0.013*** (0.001) | Number photos | 0.000*** (0.000) |
| | | R-squared | 0.874 |
| Number comments | 0.000 (0.000) | Observations | 6941 |
| | | Robust standard errors in parentheses | |
| | | * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$ | |

Results

- ▶ R-squared: 87% of variation in $\ln(\text{price})$ explained by model
 - ▶ Remaining unexplained 13% variation due to idiosyncratic tastes of winning bidder
- ▶ Sentiment score: 1% increase in sentiment score causes 0.199% increase in price
- ▶ Number of bids and bidders: interpretable as bids per bidder
- ▶ Reserve: higher price for an auction with reserve. Why?

Results: Sentiment Score

- ▶ Average vehicle price = \$31,000
- ▶ Suppose we have one such vehicle with sentiment score of 0.5. All else constant, an increase of sentiment score from 0.5 to 1, i.e. a 100% increase is given by:

$$(2^{\beta} - 1) \times 100 = (2^{0.199} - 1) \times 100 = 14.8\%.$$

Why? See next slide...

Remember:

$$\ln y = \beta \times \ln(\text{Sentiment score}) + \lambda x + \alpha \gamma$$

Suppose we increase Sentiment score by 100%, then

$$\text{Sentiment score}_{new} = 2 \times \text{Sentiment score}.$$

Then

$$\begin{aligned} \ln(y_{new}) &= \beta \ln(2 \text{Sentiment score}) + \lambda x + \alpha \gamma \\ &= \beta \ln(\text{Sentiment score}) + \lambda x + \alpha \gamma + \beta \ln(2) \\ &= \ln(y) + \beta \ln(2) \end{aligned}$$

$$\ln(y_{new}) - \ln(y) = \beta \ln(2)$$

$$e^{\ln(y_{new}) - \ln(y)} = e^{\beta \ln(2)}$$

$$\frac{y_{new}}{y} = 2^\beta$$

$$100 \times \left(\frac{y_{new} - y}{y} \right) = (2^\beta - 1) \times 100$$

Results: Robustness and Sparsity

Potential problem: Loss of estimator efficiency due to high dimensionality

Table 4: Variables in vector γ

| Variables | Type | Description |
|----------------|----------|--|
| Make-model | nominal | Unique make and model of vehicle (encoded as 264 dummy variables). |
| Year | discrete | Model year of vehicle. |
| Interior color | nominal | Interior color of vehicle (encoded as 13 dummy variables). |
| Exterior color | nominal | Exterior color of vehicle (encoded as 13 dummy variables). |

291 control variables, 309 total covariates against $\sim 7,000$ observations

Robustness and Sparsity: Solution(s)

- ▶ Use domain knowledge
 - ▶ Relies on accuracy and correctness of researcher
 - ▶ Use lasso-inferential regression method
 - ▶ robustly selects controls, uses the data to decide
1. Double-selection — Belloni, Chernozhukov, and Hansen (2014)
 2. Partialling-out — Belloni et al. (2012)
 3. Cross-fit partialling-out — Chernozhukov et al. (2018)
- ▶ All 3 methods will estimate β and λ but will use lassos to select a subset of γ . α is not estimated.

$$\ln y_t = \beta \times \ln(\text{Sentiment score}_t) + \lambda x_t + \alpha \gamma_t + \varepsilon_t$$

Table 5: Lasso Linear Estimation Results: ln(Price)

| | (1) Double-Selection | (2) Partialing-Out | (3) Cross-Fit Partialing-Out |
|----------------------|-------------------------|-----------------------|---------------------------------|
| ln(Sentiment score) | 0.161*** (0.022) | 0.137*** (0.023) | 0.127*** (0.024) |
| Reserve | 0.250*** (0.011) | 0.275*** (0.011) | 0.288*** (0.012) |
| Number bids | 0.007*** (0.001) | 0.007*** (0.001) | 0.007*** (0.001) |
| Number bidders | -0.013*** (0.001) | -0.013*** (0.002) | -0.014*** (0.002) |
| Number comments | -0.000 (0.000) | -0.000 (0.000) | -0.000 (0.000) |
| Milage | -0.000*** (0.000) | -0.000*** (0.000) | -0.000*** (0.000) |
| Number modifications | 0.003*** (0.001) | 0.002*** (0.001) | 0.003*** (0.001) |
| Number known flaws | -0.030*** (0.002) | -0.031*** (0.002) | -0.033*** (0.002) |

Table 6: Lasso Linear Estimation Results: Continued

| | (1) | (2) | (3) |
|---------------------------|---------------------|---------------------|--------------------------|
| | Double-Selection | Partialing-Out | Cross-Fit Partialing-Out |
| Number views | 0.000*** (0.000) | 0.000*** (0.000) | 0.000*** (0.000) |
| Number photos | 0.000*** (0.000) | 0.001*** (0.000) | 0.001*** (0.000) |
| Observations | 6941 | 6941 | 6941 |
| Number potential controls | 289 | 289 | 289 |
| Number controls selected | 162 | 162 | 171 |

Note: Robust standard errors in parentheses.

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

Conclusion

- ▶ What does sentiment score represent?
 - ▶ Implications for causality
- ▶ Does positive sentiment cause people to bid more?
 - ▶ $\text{corr}(\text{Sentiment score}, \text{Number bids}) = -0.084$
 - ▶ $\text{corr}(\text{Sentiment score}, \text{Number bidders}) = -0.080$
- ▶ Can we explain sentiment score?
 - ▶ $R\text{-squared} = 0.14$

Conclusion: Sentiment vs Useful Information

There is both irrational emotional information, i.e. sentiment, and also useful private information expressed in the comments.

c.f.

There are pictures of the car literally underneath a lift so it seems like a very small effort to put the car on the lift to get undercarriage pictures. It is unfathomable to me the seller isn't willing to put in that small of an effort. If the undercarriage is as clean as they claim it is a difference of easily multiple 10's of thousands of dollars would be had.

Combine that with the caginess answering questions and erroneously listing it as a V-Spec originally and this deal smells real bad.

Conclusion: Sentiment vs Useful Information

...versus...

Just checked out your instagram. Great Collection you got going on!

and

Makes sense, Thanks for the response brother!

Conclusion: Extensions

- ▶ Sentiment analyzer unable to differentiate between pure sentiment and useful information
- ▶ How could one do so?
 - ▶ Aspect based sentiment analyzer for this corpus
 - ▶ Topic model to categorize comments

Thank You!

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