Using Game Theory to Model Review Manipulation in E-Commerce

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Abstract

In this project, we aim to use methods from evolutionary game theory to model how susceptible online retailers are to review manipulation, also known as "fake" reviews. By analyzing the equilibriums of our derived replicator equation, we were able to determine the dominant population within our model. While we were able to use our model to further understand this problem, it is reasonable to conclude that a more complex analysis is needed to provide a better understanding of review manipulation.

1. Introduction

Within the past decade, online shopping has risen significantly among consumers. According to a 2016 Pew Research Center survey, about 80% American adults use the internet to shop. This is a stark contrast to the 22% of Americans who shopped online in 2000 (Smith et al, 2016). Quoting convenience, better prices, and variety as some of the various reasons for online shopping, along with the exponential growth in access to technology, it easy to see why participation in ecommerce has risen in recent years (Miller, 2014).

As the number of online shoppers has grown, the number of retailers has also increased. Online market places, such as Amazon and eBay, have risen in popularity and make up around 45% of online purchased goods (Wallace, 2017). In these marketplaces, multiple retailers often offer similar, if not the same, goods for the consumers to buy. This not only presents a challenge to the consumer when choosing how to spend their money, but also creates a fierce competition between sellers. To help solve this problem, consumers

often turn to reviews to learn more about the sellers and their products. According to Hu et al (2007), there is a positive relationship between the average (mean) review scores and product sales(1). Numerous studies have also shown that higher rated items have more visibility on websites, which in turn increases the chance of selling their product (Lappas et al, 2016). This means that online reviews have substantial impact on retailers' sales and profits. As the market has grown more competitive, sellers have looked to review manipulation as a way to stay ahead. This manipulation can be done in several ways. Many of the retailers that use this method mainly post fake positive reviews about their own company. Other retailers go as far as posting fake negative reviews about their competitors. Some companies offer what is known as incentive reviews, where they send free products to a consumer with the promise that the consumer will then write a positive review about the company. As these review manipulation practices has become more prevalent (around 15-30% of reviews are fake), there has been a slew of new review-authoring companies that offer their services to write these fake reviews (Lappas et al, 2016). E-commerce relies more heavily on the trust of the consumer than its traditional counterpart. Because shoppers cannot physically see the product, they are forced to depend on the reputation of the seller, and this reputation is often garnered by the sellers reviews. This review manipulation practice is very harmful to a market that relies heavily on this trust. So much so, that in 2015, Amazon filed a lawsuit against over 1000 review-authoring companies. Citing that these companies threated to undermine the trust that customers and the vast majority of sellers and manufacturers place in Amazon(Gani, 2015).

The purpose of this project is to 1) apply concepts in evolutionary game theory to model the behavior of a population of sellers to determine how susceptible they are to participating in review manipulation,2) determine the dominant population within this model and 3) evaluate the effects that size of the population and the threshold have on the equilibriums of our model.

2. Model

Consider a seller of a marketplace with a population of sellers, N. The seller is faced with two decisions, to be an honest seller H who does not post fake reviews, or a dishonest seller D who participates in review manipulation.

The binomial distribution of this decision is used:

$$\binom{N-1}{m} x^m (1-x)^(N-1-m) \tag{1}$$

Where x is the probability of having an honest seller and m is the number of honest sellers. In order for consumers to have trust in these sellers, the population must meet a threshold c, of honest sellers. If the threshold is met then honest sellers will receive a benefit of hb and dishonest sellers receive a benefit of db. If they do not reach this threshold then honest sellers will experience a cost of hc and dishonest sellers, a cost of dc.

In order for sellers to become dishonest, the the benefits of being dishonest should be higher than being honest, so we can say that $db > hb$. If consumers do not believe the reviews of the population, then honest sellers only lose out on profit. Dishonest sellers not only lose out on profit, but also on the money and time spent to write these fake reviews. It is for this reason that we say that $dc > hc$. The payoff functions are:

$$f_h(m) = \begin{cases} hc & \text{if } m < c \\ hb & \text{if } m \geq c \end{cases}$$

$$f_d(m) = \begin{cases} dc & \text{if } m < c \\ db & \text{if } m \geq c \end{cases}$$

To find the value of each decision, we apply the expected value formula to each choice

$$E_h(x) = \binom{N-1}{m} x^m (1-x)^(N-1-m) f_h(m+1) \tag{2}$$

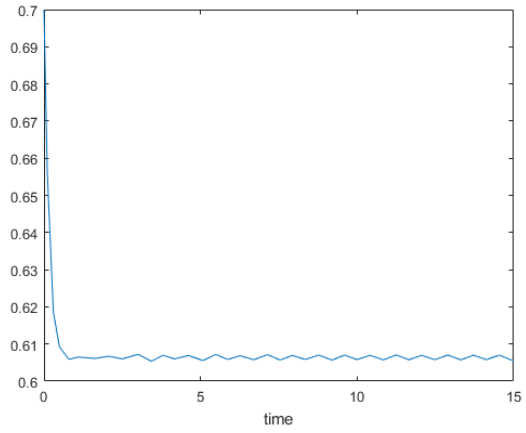
$$E_d(x) = \binom{N-1}{m} x^m (1-x)^(N-1-m) f_d(m) \tag{3}$$

To model the behaviors of both of these subpopulations over time, the replicator dynamics equation as explained in Cressman and Yi (2014) is used.

$$dx/dt = x(1-x)(E_h - E_d) \tag{4}$$

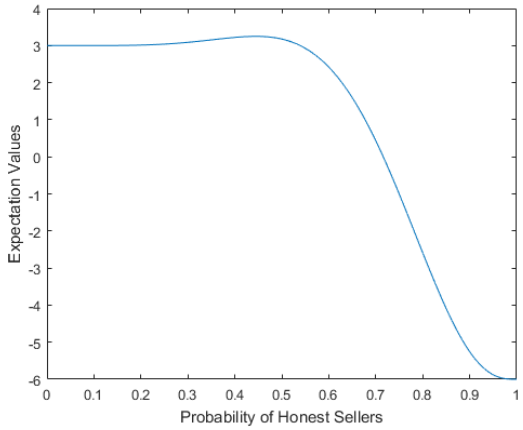
3. Analysis

We graph the replicator equation to see the behavior of our model over time with $x_0 = .7$ and the threshold proportion, $K = .6$. Here we see that the



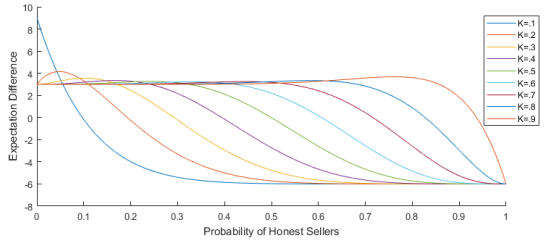
probability of honest sellers decreases until it reaches a value slightly above the threshold.

To determine the dominant type of seller of this population, we can determine the equilibriums of this model to find the best decision for the seller to make, this method is explained in Cressman and Yi (2014). To find the inner equilibrium and its stability, we graphed the difference of the expectation values of the honest and dishonest sellers.



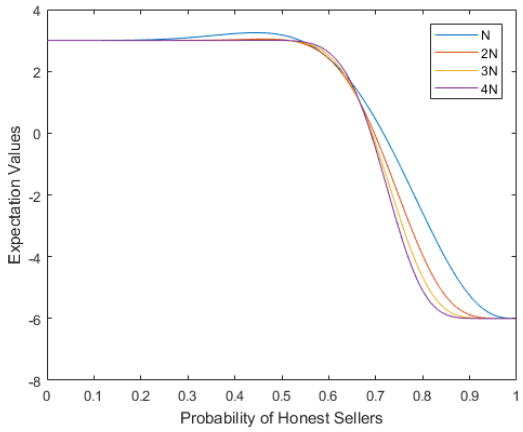
Based on this graph we can determine that the equilibrium is not stable and expectation values decrease before converging to some number. This shows that within this model with these given parameters, dishonest sellers are dominating honest sellers.

Within this model we have multiple parameters that fix to a certain value. We then want to investigate how changing these parameters effect the equilibrium and the stability of the population of honest sellers. First we assess how different threshold values effect the equilibrium.



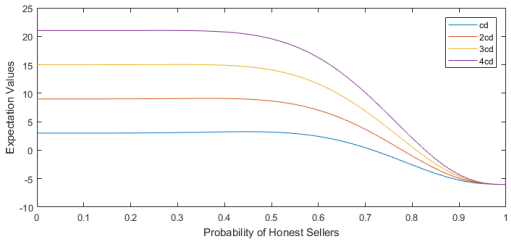
According to the data above, we can see that though the increased threshold value improves the number of honest sellers within a population, it does not stabilize the honest population itself.

Since we have a finite population of sellers, we want to see if the population size had any effect on the behavior of the equilibrium. Here we set the threshold to be $K = .7$. As seen in the graph, as the population increases, the equilibrium point gets closer and closer to the threshold value, but the population is still unstable



Another parameter we can explore when trying to analyze the stability of the equilibrium is the effects of different cost values. We want to see if changing the cost of the dishonest population impacts the stability of the

honest population. To do this we increased the cost by increments of itself (we keep the threshold constant at $K = .7$)



As seen above, as we increased the cost that dishonest sellers experienced, it required a higher proportion of honest sellers to exist for a seller to become dishonest.

4. Conclusion

Through our modeling, we determine that the benefit of dishonest sellers must be higher than that of honest ones. From our model, we saw that because of this, sellers will always choose to be dishonest as long as the required threshold of honest sellers is met. Factors such as population size, threshold proportion and costs have little to no effect on this behavior. By this reasoning the honest population will never be considered stable. Just as in real marketplaces, such as Amazon and eBay, if sellers believe that customers will believe their reviews, they are more likely to behave in fraudulent behavior to increase their sales. That being said, it is also reasonable to conclude that this model alone is not enough for us to get a measure of the behavior of these sellers as our initial assumptions limits predetermines the stability of the honest population.

Moreover, this model can act as a basis for more complex analyses such as, exploring the behavior of sellers who act in different types of review fraud like seller written reviews or incentive reviews. This model can also be used to measure the effects that different policing models have on sellers decisions. For example, in recent months different online marketplaces have looked to cracking down on dishonest sellers by filtering out seemingly fraudulent reviews or forcing people to verify their purchases before posting reviews. By using these methods to model these behaviors, we hope to find a solution that will eventually eradicate the use of fake reviews from e-commerce.

5. References

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