Optimal Selection Model for Arbitrage in Eve Online

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Abstract

Arbitrage in Eve Online is an interesting problem because imagine you were to buy a TV on Facebook Marketplace to sell on eBay for 20% more but instead of going to pick up the TV and driving home with it, there was a high likelihood you get carjacked and robbed on the way home the question then becomes when is it a good idea to go pick up the TV.

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1 Introduction

There's four parts to a model for arbitrage in Eve Online first, we need to identify candidates i.e. what are potentially profitable trades? Second there's some amount of time it will take to execute the trade, so we need to have some idea of future price, in Eve trades take quite a while, we can estimate the time given path length n and the rate parameter λ (jumps follow a Poisson Process) after this we can construct a 98% confidence interval for the price of the asset at time t using the asset's variance retrieved from historic data, Monte Carlo simulation, and Geometric Brownian Motion. Third we need to calculate the probability of failure, as of writing there does not exist a good way to do this and in all reality there needs to be a separate paper written about just calculating this function so for the purposes of this paper I will write this $P(F)$. Lastly since the result of failure is total loss of all invested capital the problem is somewhat similar to something like gambling, hence I use the Kelly Criterion here to estimate the maximum ratio of net capital to invest in a given run, plugging in the previous values we calculated: $f^* = (1 - P(F)) - \frac{P(F)}{b}$ where b is our payout in this case expected profit π which is estimated in the second step.

2 Finding Trades

Opening the game's market browser and searching for trades is quite simple, and the game will just tell you what the margin is how far it is and what the trade is from this information we form the basis of the rest of the paper.

3 Asset Price Estimation

A concern associated with having to fly to get an item is that the item may be worthless by the time you get back.

3.1 Estimating Time

The amount of time that you're expected to take follows a Poisson Process for some rate parameter λ where λ is the average number of jumps per minute the path you take typically follows some path length n so we're looking for the time of the $2n$th arrival (this is because you have to go there and back) denoted T_{2n} which is modeled $Gamma(2n, \lambda)$ from this the expectation of a Gamma distribution is $E(T_{2n}) = \frac{2n}{\lambda}$[1] hence the expected amount of time for a path length $2n$ is $E(T_{2n})$ for the remainder of the section this is denoted Δ.

3.2 Item Price Model

The item pricing model used is Geometric Brownian Motion we assume that the item will have some drift μ and volatility σ these are able to be accurately estimated using the game's API since Eve's publishers understand that players like me have autism, μ is calculated by fitting a Linear Regression to the latest high frequency market data as we're looking at drift on the day / on the hour in order to predict within the next hour or so a confidence interval for price, σ is a little easier as it's just the historic standard deviation of the item price as a ratio of the item's current value. Using these two parameters as well as the initial asset price S_0 we can then plug in these values to the analytic solution for the Geometric Brownian Motion SDE[4]

$$S_t = S_0 \exp((\mu - \frac{\sigma^2}{2})t + \sigma W_t)$$

From this we can then realize a single Geometric Brownian Motion over Δ from now on we will call this S_Δ for a realization over Δ.

3.3 Monte Carlo

A number of different realizations exist for S_Δ this is due to the the Wiener Process W_t an interesting thing to note about the Wiener Process is that it's Normally Distributed hence the realizations of S_Δ are also Normally Distributed[3]. Using this information it's possible to construct a confidence interval on a set of realizations. Monte Carlo allows us to get a good picture of the probability distribution of realizations. From here it's possible to simply construct a confidence interval I i.e. $\{\mu_0 \pm Z_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}}\}$ where μ_0 is the mean of realizations on S_Δ.

4 Problem Formulation and Kelly Criterion

The problem of Arbitrage in Eve Online is more similar to something like gambling in real life more so than something like trading stock across markets although it's still Arbitrage there's a level of risk only seen in gambling since in real life losses are only partial where as in Eve if you get ganked and die you lose everything.

4.1 Kelly Criterion

A good estimate for how much money you should risk in a game where you could lose all of your money is the Kelly Criterion and is formulated $f^* = (1 - P(F)) - \frac{P(F)}{b}$ where b is the payout ratio[2] in this case the margin on the trade. Now some may think the Kelly Criterion is still too risky in this case you should find a different game. In all seriousness this can be taken as the maximum amount of capital to risk on a given run although it could also be interpreted as the optimal amount of capital to risk on a given run. The amount of capital to risk is $k = K \cdot f^*$ where K is player net worth.

5 Discussion

5.1 Failure Calculation

$P(F)$ may be estimated a number of ways potentially you may be able to model the issue as a differential equation. Estimate some function and solve for parameters using MLE collecting real world data in the game. Another way may be to use RL I think this would be the most accurate approach but would probably require a number of runs from the player in order to get a good estimate of how likely a specific individual is to fail want to fine tune the model to a specific player but also consider the potential issues that may arise if you always fail your runs the probability of failing future runs is not zero i.e. past results is not an indicator of future failure or something like that there is probably a real mathematical relationship between the amount of capital invested into the run k and the probability distribution of the random variable F i.e. how likely you are to fail based on k or other information. I suspect F has a pdf which is possible to solve for.

5.2 Additional Things

In addition to the previously stated Failure calculation we also want to know λ which is the average rate at which we're able to make jumps in min^{-1}.

References

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[4] Sheldon Ross. *Introduction to Probability Models.* Academic Press, 11th edition, 2014.