EVE: Online as a Potential Microeconomic Model

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Abstract

EVE: Online (EVE) is a video game with one of the largest virtual economies in existence. The question reigns, can a video game economy function realistically according to microeconomic theory? To test this, I examined multiple variables for a commodity in *EVE* over an extended period. I found that the commodity's price and demand acted in the same way that real-world commodity prices do. This suggests that *EVE*'s economy adheres to microeconomic theory. Knowing this, there are many useful applications for *EVE* as a tool to measure and predict microeconomic behavior and possibly even macroeconomic behavior.

Introduction

EVE: Online (EVE) is a video game set in outer space with seemingly little application for scholarship in economics. *EVE* may be a video game, but it is still useful in economics. Designed by Icelandic Economist Dr. Eyjólfur Guðmundsson, *EVE* has been affectionately nicknamed Spread Sheets, Math Simulator, and the most boring, thrilling game ever. The game is known for its steep learning curve and applicable mathematics, statistics, and economics. Guðmundsson calls the game a "national economics institute, statistics office and central bank" that models real-world economics, with an in-game economy estimated to be worth over 18 million USD (Gilbert 2014). If this is true, then the laws of supply and demand should hold. The law of demand states that, holding other factors constant, at higher prices people should demand less. At lower prices, people should demand more. The law of supply states that at high prices, companies want to supply more product and at lower prices less (Perloff 2009, 14). If these laws hold, at some price—what economists call the equilibrium market price—the quantity supplied should equal the quantity demanded. The purpose of this paper is to understand how well virtual market economies can operate according to basic economic principles. Do the online markets that evolve in *EVE* conform to the basic beliefs about supply and demand? In other words, can we find evidence that the laws of supply and demand hold in the virtual world?

Background

The *EVE: Online* market is managed and led by Dr. Guðmundsson and his team of economists. They designed the market such that there is an unlimited amount of material to be collected throughout the universe. However, collecting materials takes time and resources. In other words, there are always opportunity costs and trade-offs for collecting materials. Due to these trade-offs, materials collected gain value. With unlimited resources, markets would fail to form, as every player could easily collect all the material supplies they wanted. Instead, much like the real world, players specialize and exchange in the market through the medium of money. Thus, this is a capitalist and free-trade model. Players may earn as many resources as they can, if they work to get those resources. But as we have seen in the real world, trying to start from nothing and rise to the top is a difficult task. Markets and businesses are established by real people in real time, with tens of thousands of players interacting within the virtual environment. Through these interactions, they can build and create wealth by partaking in economic transactions powered by free trade. Furthermore, players are free to establish businesses and create rules in an attempt to become significantly wealthier by way of specialization and optimization. *EVE* is a financial sandbox for businesses and free agents alike to flourish on a wave of economic proficiency. Because *EVE* successfully mimics real-world market conditions, it is an excellent place to study human behavior and test the "laws" of economics.

Literature Review

Branes's 2016 analysis of the functionality of *EVE: Online* commodity markets explains that the supply and demand for products and commodities are set by players. When players request to buy or sell an item, they create a bid order. These orders function the same way real-world commodity markets function, such as the Chicago Mercantile Exchange. The higher the price on a sell order, the less demand there should be for it. Sell order prices are naturally more expensive than buy order prices. Suppliers would like to sell their products for the highest price possible, while buyers would like to pay the lowest price possible. Equilibria are formed through these market interactions.

Competitive markets have been studied with experimental models (Smith 1962). *EVE* can be viewed as a perfectly competitive market if it has all four of these properties (Perloff 2009, 225):

1. Consumers believe that all firms sell identical products.
2. Firms freely enter and exit the market.
3. Buyers and sellers know the prices charged by firms.
4. Transaction costs are low.

Because these properties are present in *EVE*, we have access to a new kind of experimental mechanism for observing perfectly competitive markets in the microeconomy. Dr. Guðmundsson, the chief economist at CCP Games, agrees. He states, "I had seen that in experimental economics they were running experiments with 20 or 30 people and getting results that were really in line with theory. So, I thought, with tens of thousands in the same boat, this could be awesome" (Casey 2010). Though not specifically addressing fantasy digital markets, these papers and comments reinforce my thesis that *EVE* markets should exhibit standard economic outcomes.

EVE has many firms, which are price takers and sell the same product. The perfectly competitive assumptions hold: many buyers, many sellers, perfect information, homogeneous products, and free entry and exit (Perloff 2009, 225). In this way, we should be able to view *EVE* as a holistic economic system. Although game theory provides useful insights for the real world, it plays a negligible role in *EVE* because all participants have perfect information, or at least the same information. Sociological and psychological barriers and biases can interfere with trade (Hansen 1985). With weak sociological and psychological barriers and perfect information, only weak economic games should form. However, there are rare cases when a large group of players will collect significant proportions of the total market supply of a commodity and destroy all of it to see the price skyrocket, thereby creating a monopoly and harnessing market power. These players are able to sell the commodity at significantly higher prices because of the shortage; however, *EVE* markets are not very susceptible to economical games.

Markets and auctions, specifically online auctions, have a long history of analysis (Klemperer 1999, Hansen 1985, Liu and Shiu 2013). As a result, there are clear expectations about how *EVE* markets should behave. With nearly perfect information, perfect competition, and an internet setting, *EVE* should abide by the principles of auction theory. That is, the more information available to each player, the easier the auction is to solve. This is why transactions take place rapidly in *EVE*. This study will further the limited research in online and video game market economies as valuable embodiments of real-life economies (Salter and Stein 2016, Cavender 2015).

Model and Data Description

In my research, I focus on one particular commodity market, the market for Tritanium. This element is the most plentiful and most traded item in the game. It also has the lowest price. I follow this commodity market closely to see if the same variables that affect real-world prices similarly affect the video game price.

Basic economics suggests that demand is influenced by the number of buyers, income, prices of substitute products, preferences, and expectations about the future. Unfortunately, due to the nature of *EVE*, I was unable to gather data on some of these key factors, particularly the prices of complementary and substitute products. I also do not have information on consumer preferences. Supply determinants include the number of sellers, the prices of inputs, technology, and expectations about the future. Natural disasters or government regulation can also affect supply choices. I account for this by using a dummy variable for battles in the game. Again, in this case, I have little ability to collect data on some of the determinants, including the price of inputs (e.g., the value of game players' time) or expectations about the future.

However, this lack of data is not as detrimental as it might seem at first glance. The determinants of demand and supply are the factors that will shift the curves. Demand can increase, meaning at any price, people want more than before. Or, demand can decrease—at any price, people want less than before. Supply works analogously. Though this is an important part of market analysis, I am interested in a more fundamental question: whether the law of demand and supply holds. Thus, I can analyze the factors that shift the supply and demand curves—holding these factors constant—and ask whether there is evidence that demand exhibits a downward sloping relationship between price and quantity. Similarly, supply exhibits an upward sloping relationship between price and quantity. Therefore, the auction literature is relevant.

As explained in the literature review, the way items are traded in *EVE* allowed me to look at both sell order and buy order prices and quantities. The buy orders represent the demand for Tritanium and the sell orders represent supply of it. This means that the bottom half of the demand curve and the upper half of the supply curve would be described from the data. The two lines from the data can be constructed, and from them, equilibrium can be identified. Figure 1 illustrates this concept.

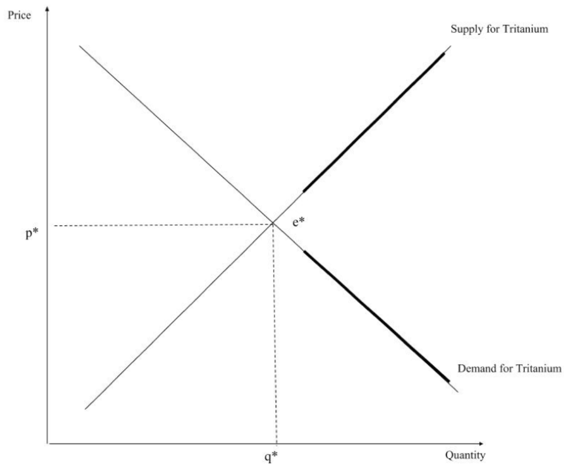

Figure 1. The market for Tritanium.
Note: The bolded sections in the figure represent the distribution of price and quantity data for *sell orders* (supply) and *buy orders* (demand).

To estimate the equilibrium price, I use the following relationship:

$$LogSOPrice = ß_0 + ß_1 SOQuantity + ß_2 BOQuantity + ß_3 InteractionBOQuantity/SOQuantity + ß_4 LogBOPrice + ß_5 \#Players + ß_5 Battle$$

Sell order price is the dependent variable. Independent or explanatory variables include the *sell order quantity in billions*, *buy order quantity in billions*, an interaction term between the two quantities, *buy order price*, the *number of players online*, and a dummy variable for battles. This dummy variable indicates whether or not a battle occurred on a given day. As is standard in econometric literature, both the sell order price and the buy order price are entered as the natural log of the price. This allows us to think about changes in percentage terms, rather than the arbitrary monetary metric of *EVE* (Gujarati and Porter 2010, 175). With these variables and relationships in mind, I arrived at the following hypotheses, based on economic theory.

Hypothesis 1: As the *sell order quantity* and *buy order quantity* increase, we expect the market equilibrium price (*sell order price*) to decrease. Per the law of demand, larger quantities available are associated with lower equilibrium prices.

Hypothesis 2: The supply and demand in *EVE* markets are affected by the same factors, and in the same way, that shift supply and demand in the real world. More battles should be associated with higher prices. When a battle is fought, material is destroyed. This loss in material causes a rise in demand for whatever was lost. Thus, as the demand increases, so should the price. Similarly, as the *buy order price* and the *number of players online* increase we should find that the *sell order price* increases also. Because buy orders represent the demand for Tritanium, as the price that buyers are willing to pay increases, then so will the price the sellers are charging. Furthermore, as the population in the game increases so will the demand for all products, increasing the *buy order price* and then *sell order price*.

All data concerning prices and quantities were collected from *EVE-Markets* (Muscaat 2017). This website is managed by hundreds of people who play the game. Battle information was collected from *EVEMaps* (Wollari 2017). I assign a 1 to battle if damage was done to any in-game property. Player data was from *EVE-Offline* (Chribba-OMG Labs 2017), which tracks the number of players online every hour. I collected data over a span of 100 days (N = 100); data were collected at the same time each day. Descriptions, summary statistics, and further information including predictions are found in table 1.

Table 1. Description of the data.

Variable	Description	Expected Relation to the Dependent Variable	Mean or Percent	Std. Dev.	Minimum	Maximum
Sell Order: Price	This is the average price at which players sold an item in their sell order on the day. It will be measured in ISK (game currency).	N/A	5.949	.0455	5.830	6
Sell Order: Quantity	This is the quantity that players sold when they put in a sell order on the day. It will be measured in billions of units. It is also the quantity demanded of sell orders.	Negative	77.11	15.95	60.39	122.90
Buy Order: Price	This is the average price at which players purchased a buy order of an item on the day. It will be measured in ISK.	Positive	4.571	.0612	4.500	4.82
Buy Order: Quantity	This is the quantity that players got of an item when they put in a buy order on the day. It will be measured in billions of units. It is also the quantity demanded of buy orders.	Negative	94.44	7.757	76.93	111.41
Number of Players Online	This is the number of players that are online during the specific date.	Positive	28,710.48	2,418.88	24,622	35,120
War Reported? 1 = yes 0 = no	This is a dummy variable, whether or not a war occurred on the day. I will only count wars in which ships or ISK are destroyed.	Positive	6%	.2387	N/A	N/A

From the summary statistics, I observe that the mean *sell order quantity* is actually lower than that of *buy order quantity*: 77.11 billion and 94.44 billion respectively. This is appropriate because economic theory would suggest that at higher prices, less is demanded. The expected correlation between *sell order quantity* and *buy order quantity* should, therefore, be negative. Correlations between all variables can be found in table 2.

Similarly, as *buy order price* increases so should the *sell order price*. The summary statistics indicate this is true. The mean *buy order price* of 4.571 is appropriately lower than the mean *sell order price* of 5.949, thus supporting my supposition that *buy orders* and *sell orders* can act as demand and supply. The observed difference in prices indicates that we are to the right of the classical equilibrium point in our market (figure 1).

The other two important variables in my model are *battles* and *number of players online*. I predict that as the *number of players online* increases, the overall demand, and therefore the price, for Tritanium should increase. *Battles* should have a positive effect on price because the repairs that are necessary for rebuilding and construction involve trillions in game currency (ISK) to repair. This increase of demand for rebuilding materials would result in an increase in *sell order price*. We observe that there is a 6% chance that there will be a battle on any given day and that player population will fluctuate between 24,622 and 35,120 players on any given day. Notice that the *number of players online* has a large standard deviation of 2,418.88 players. Thus, I anticipate that the market price will be highly responsive to whether there are people playing *EVE*.

Table 2. Correlations between variables.

	Sell Order Price	*Sell Order Quantity*	*Buy Order Price*	*Buy Order Quantity*	*Number of Players Online*	*Battle* (1 = Yes)
Sell Order Price	1					
Sell Order Quantity	0.0017	1				
Buy Order Price	0.4327	0.1118	1			
Buy Order Quantity	0.5775	-0.0786	0.0143	1		
Number of Players Online	0.3413	-0.3881	0.1220	0.2328	1	
Battle (1 = Yes)	-0.0859	0.1490	-0.0009	-0.0024	-0.0886	1

The most notable features I observe from the correlation matrix are the strong, positive correlations between *buy order price* and *buy order quantity* as associated with the dependent variable *sell order price* (r = 0.4327 and r = 0.5775 respectively). This makes sense and suggests *buy orders* are the demand for Tritanium; and thus, supply is very much determined by demand.

The independent variable *battles* has a weak, negative correlation with *sell order price* (r = 0.0859). This suggests that *battles* will be relatively unimportant when determining *sell order price*. In a market where quadrillions of ISK are traded each day, an average battle costing less than 100 billion ISK will not have a substantial effect on the economy overall. The weak, positive relationship between the *number of players online* and *sell order price* (r = 0.3413) is consistent with predictions based on the law of demand. Although the relationship is weak, it may still be significant because the number of players online is an exogenous factor of the game.

Regression

To examine the relationship between the variables and test whether the laws of supply and demand hold in *EVE*, I use multi-variate regression analysis. This is a standard econometric technique that allows me to summarize the relationship between a dependent variable conditional on several outcomes and independent variables. The final regression is reported in table 3.

Table 3. Regression results.

Variable Name	Estimated Coefficient (Standard Error)	*p*-Value
Buy Order Quantity in Billions	-.00203 (.00069)	0.004
Sell Order Quantity in Billions	-.00331 (.00072)	0.000
Interaction Term Between Sell Order Quantity and Buy Order Quantity	.00003 (.000008)	0.000
The Natural Logarithm of the Buy Order Price	.69048 (.10312)	0.000
Battle (Yes Or No)	-.00280 (.00203)	0.170
Number of Players Online	8.58e-07 (4.11e-07)	0.039
Constant	.46484 (.18679)	0.015

Note: The dependent variable is the natural logarithm of the sell order price.
$R^2 = 0.6558$ Adjusted $R^2 = 0.6336$ N = 100

It is important to note the issue of simultaneous equation systems between my two variables, *sell order price* and *buy order price*. In econometrics, this means that the two variables both depend on the other and its error terms. Because of this relationship, the standard ordinary least squares (OLS) regression analysis may be both biased and inconsistent. For this study, the uncertainty of the error term hindered the development of an instrumental variable to describe the relationship between *sell order price* and *buy order price*. The relationship I found still holds the theoretically anticipated sign but the adjusted R^2 and coefficients may be slightly inaccurate.

In the final regression, I observe an adjusted R^2 of 0.6336, explaining 63.36% of all the variation in *sell order price* by the variation in the six independent variables. For regressions based on social sciences data this adjusted R^2 is quite strong. The final regression therefore demonstrates that I have a relatively strong ability to predict the *sell order price*.

Taking the natural logarithm of both *buy order price* and *sell order price* simplifies comprehension variable relationships. As opposed to calculating miniscule increases and decreases in the arbitrary online currency, I can interpret the estimated coefficients as percentage increases and decreases. An increase in *buy order price* by 1% will increase the *sell order price* by 0.69%. This is consistent with the law of demand and is statistically significant ($p < 0.05$).

An increase of 1 ISK of the *sell order quantity* or the *buy order quantity* reduces the *sell order* price by 0.3% or 0.2%, respectively ($p < 0.05$). In other words, higher quantities available result in a lower market equilibrium price, just as we would expect given the law of demand.

An interaction term allows us to see if there is a compound effect created by *sell* and *buy order quantities*. I find that if both the *sell order quantity* and *buy order quantity* increase at the same time, their combined ability to reduce the *sell order price* is mitigated by 0.004% ($p < 0.05$). This is also consistent with the classic supply and demand model. We know that when quantity demanded increases, then the supply price will decrease. However, if quantity demanded increased at the same time for both types of transactions, the combined effect shouldn't be as large because demand price is also falling.

As the *number of players online* increases by 1000, the *sell order price* increases by 0.0858% ($p < 0.05$). Because demand is partly dependent on the market size, more people will shift the demand curve to the right, resulting in a higher market price. The variables discussed so far have been statistically significant and of the expected sign, indicating that the *EVE* market for Tritanium conforms to basic economics principles.

Battles was my only statistically insignificant variable ($p = 0.170$). Although the sign on the estimated coefficient is positive, indicating that more battles are associated with higher prices, I cannot say with confidence that there is really an effect. We see that if there is a battle on a day, the *sell order price* of Tritanium will decrease by 0.28%. This is logical because if there was a battle, the *sell order quantit*y demanded would increase, causing the *sell order price* to decrease. If I had looked at the local economies where the *battles* had taken place, I may have seen more conclusive results with the battles variable. Because the battles are such small economic changes in such a very large economy, their effects are not as significant. It is also possible that the effects of battles on price don't emerge until several days afterward when people start to rebuild.

Conclusion

The evidence suggests that *EVE* adheres to real-world microeconomic assumptions. It appears that game theory and auction theory are both testable mediums in *EVE*. Furthermore, the data show a relationship between supply and demand that are accurate according to microeconomic theory. My research indicates that further experimentation would be worthwhile. Next time, perhaps, I would create a variable that accounts for the dual relationship between *sell order price* and *buy order price* and their error terms. If my results are found to be accurate on multiple or all occasions, it is reasonable to say that economists can use *EVE* and possibly other video game environments to study economics. If game designers were to enforce fiscal or monetary policy, they would observe the effects of that policy as created by real people. *EVE* functions as Dr. Guðmundsson intended: an observable universe that abides by and functions in all the ways that classical economic supply and demand would suggest. Knowing that *EVE* functions in an accurate economic way shines new light on modern econometrics.

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