Exploring the Tragedy of the Commons:

Applications to Consumption Behavior During a Pandemic

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i. Abstract

The objective of this research is to quantify a Tragedy of the Commons scenario in regards to consumer behavior as a result of a pandemic, such as COVID-19. This is quantified by measuring the amount of time that is required for the entirety of the consumable resource, "food," to be exhausted. In order to evaluate the impact of a pandemic, the input of perceived scarcity is varied, which refers to how scarce consumers expect food to be in the future term. The model uses the agent-based modeling software NetLogo, and uses the built-in "ticks" primitive in order to assess units of time. After evaluating the impact of perceived scarcity, my findings show that the amount of ticks required to cause such a dilemma greatly vary once perceived scarcity reaches a certain threshold point. I conclude that the input most likely is influenced by another psychological disposition, explaining the variance being this sporadic.

I. Introduction

As a concept, the Tragedy of the Commons applies directly to the issue of scarcity in markets. The dilemma arises when all agents of the market seek to maximize their utility through consumption, culminating in a complete exhaustion of the scarce resource and the inability of agents to attain any utility once this occurs. That process is the center point for this research, as a model grocery store is used to represent the locale of the scarce resource "food."

In terms of applicability of the model, the agents represent consumers seeking to maximize their utility through consumption of food, and react to certain behavioral factors that impact consumption. The outline of the NetLogo code that portrays the dilemma of the Tragedy of the Commons itself was originally developed by Julia Schindler, under the title "a simple Multi-Agent System of the Tragedy Of the Commons" (Schindler 2012). I have modified the outline of this NetLogo code to administer the Tragedy of the Commons to the aforementioned grocery store scenario. It is also important to note that Professor Alan Isaac also made changes to the NetLogo code, in order to create a file that was compatible with NetLogo 6.

The explicit goal of my model, however, is to determine the reaction of the Tragedy of the Commons as a result of a change in perceived scarcity. It is critical to note how to quantify the consequences displayed in the Tragedy of the Commons. Referring back to how the dilemma requires an exhaustion of a scarce good, the model quantifies the intensity of the Tragedy of the Commons, as well as the dilemma never occurring, by measuring the amount of time required for Tragedy of the Commons to

occur. This is explicitly quantified by “ticks,” which are the standard time unit in modeling with NetLogo.

It is important to note that the original model by Julia Schindler was different in terms of how the model stopped the code from running, otherwise known as a stop method. In the original Schindler model, the code would stop solely if the total count of ticks reached 300. This has been modified in the presented model, as the file continues to run until the amount of scarce resources, “food,” has been exhausted. The current model will also cease to run if the amount of ticks reaches 3000, however, this is entirely a safety guideline, in case of a scenario where the Tragedy of the Commons never takes place.

In terms of change in perceived scarcity, the model includes two inputs that were not present in Schindler’s original model: “perceived-scarcity” and “unstandardized-beta-of-PS.” The unstandardized beta input is a coefficient of the perceived scarcity input, since the unstandardized beta represents the intensity of the impact that perceived scarcity has on the output. More precisely, the unstandardized beta answers the question that if perceived scarcity shifts by 1 unit, how many units will of time will shift to create a Tragedy of the Commons?

To reach the goal of determining the impact that perceived scarcity has on the creation of a Tragedy of the Commons, the input variable “perceived-scarcity” is slowly incremented, and the value of total ticks required to cause this dilemma are observed. This should portray how consumers’ expectations of scarcity in the future will influence the exhaustion of the food resource.

II. Literature Review

A. Julia Schindler; "Rethinking the Tragedy of the Commons: The Integration of Socio-Psychological Dispositions"

When discussing this model, it is essential to analyze the academic articles used as sources. First, I am utilizing the article titled "Rethinking the Tragedy of the Commons: The Integration of Socio-Psychological Dispositions" in the Journal of Artificial Societies and Social Stimulation by Julia Schindler, which is directly tied to the base code outline that I modified for the present model. The broad problem that Schindler discusses is the Tragedy of the Commons, and the dilemma's relationship with certain psychological factors that affect an agent's behavior.

The dilemma is critical in reviewing, as it is central to the proposed model. There is also substantial importance in the article, as Schindler's model that is tied to the article was used as a code outline for this proposed model.

To summarize, Schindler uses game theory and the Nash equilibria to determine certain psychological behaviors, which she then applies to "the success of resource use of a common without any top-level regulations" (Schindler 2012). Schindler also mentions Hardin's original concept of the Tragedy of the Commons in 1968. In terms of psychological inputs, Schindler defines certain "dispositions," such as "fairness to others," "cooperativeness," and "positive reciprocity" to name a few. The explicit scenario of the dilemma that Schindler chooses to portray in her article is the same scenario that Hardin devised in 1968: a green pasture, where grass is consumed by cows from herdsman, and grass acts as a scarce resource. Each herdsman wants to maximize

their utility by spawning cows to eat the grass, but if grass is exhausted as a resource, no herdsman can maximize their utility.

Overall, Schindler finds that her model "has the capacity to support the scientific understanding of the management of commons," emanating that the use of the Nash equilibria and game theory principles holds up in practice (Schindler 2012). Schindler's findings displayed that the aforementioned dispositions have a clear impact on the pattern of grass consumption. She also observed that if more than one disposition was changed, that the changed dispositions influenced each other in a way that was unpredictable surrounding the Nash equilibria.

B. Lisa Garbe, Richard Rau, Theo Toppe; "Influence of perceived threat of Covid-19 and HEXACO personality traits on toilet paper stockpiling"

As a second academic article that I will be utilizing in my model, I will be analyzing the article "Influence of perceived threat of Covid-19 and HEXACO personality traits on toilet paper stockpiling," which was published in the journal PLOS (Public Library of Science) One by Lisa Garbe, Richard Rau, and Theo Toppe. The broad problem that the group discusses is the perceived threat of COVID-19 on supplies, more explicitly in this example, toilet paper. The article focuses on excessive stockpiling, or in other words, panic buying. This causes the average consumer to be unable to maximize their utility through purchasing this inelastic good.

The problem that is discussed in the article is pivotal in regards to the proposed model, since the consequences of perceived scarcity that are portrayed on toilet paper supply will be analogous to my concentration on goods in a grocery store. The article's

analysis proves itself as an essential glimpse into how consumption patterns change when a consumer's outlook on future scarcity is uncertain.

To summarize, Garbe, Rau, and Toppe conducted an experiment with 1,029 adults, where participants expressed their perceived threat level of the COVID-19 virus. The consumption patterns of each participant was then observed, more explicitly, their consumption of toilet paper. The participants also reported other factors, such as their age and political stance.

Garbe, Rau, and Toppe conclude three main findings in their article. They explain, "First, the perceived threat of Covid-19 predicts toilet paper stockpiling. Second, Emotionality predicts the perceived threat of Covid-19 and thereby indirectly affects stockpiling behavior. Third, individuals high in Conscientiousness engage in more toilet paper stockpiling" (Garbe, Rau, & Toppe, 2020). In terms of the input of perceived threat of COVID-19, the group found that the relationship between the perceived threat and the "Shopping Frequency" had a beta value of 0.76 and a standard deviation of 0.033, while the relationship between perceived threat and "Shopping Intensity" had a beta value of 0.77 and a standard deviation of 0.033. This information proves itself as crucial to the provided model, as the model will be able to act off of real world relationships.

III. Model Description

A. State Variables and Scales

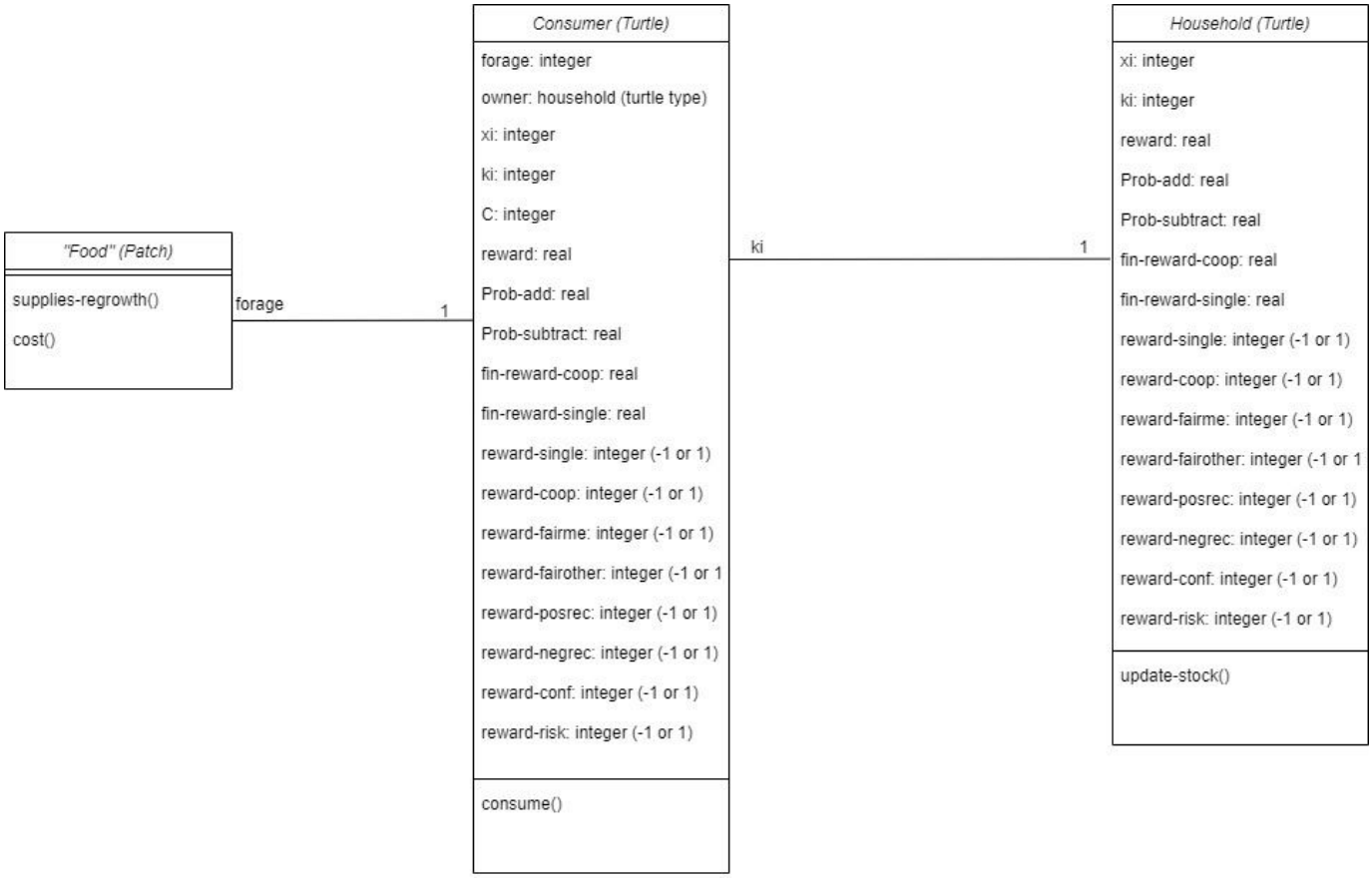
The primary entity in the model is the turtle. The turtle represents the consumer, which seeks to consume the resource "food," which is represented by the patch entity.

Both patches and turtles are built in entities in NetLogo programming. There are also multiple different types of variables. For instance, there are a multitude of variables inherent to turtles, such as xi, which is an integer portraying certain choices made by households, and ki, which is an integer portraying the amount of consumers per household. The majority of turtle variables pertain to an amount of reward that consumers receive after exhibiting a certain psychological behavior. Examples of this are "reward-fairme," which is an integer that rewards or punishes consumers for acting in a way that is fair to themselves, or "reward-coop," which is an integer that rewards consumers for being cooperative with other agents.

There are also a number of global variables in the model, which act as overall measures. One example is "cover", which is what percentage of food is left as agents consume. Other global variables include "supplies-initial-customers" and "supplies-after customers," which represent the amount of resources before and after agents consume, respectively.

Moreso relating to entities, the visual depiction of the model's entities can be observed below:

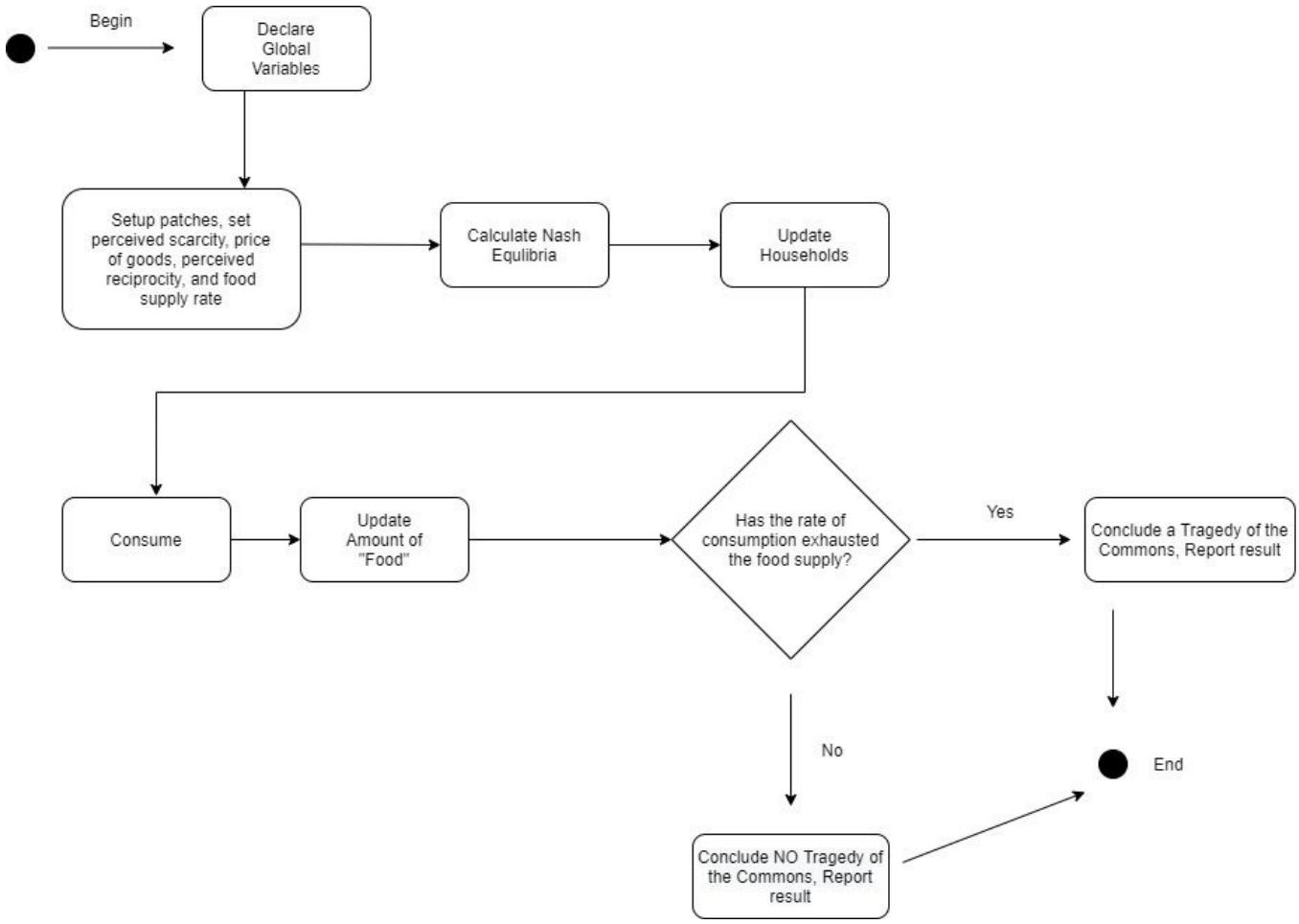
UML Class Diagram



B. Process Overview and Scheduling

The order and direction of processes in the model's code can be observed in the UML Activity Diagram below:

UML Activity Diagram



C. Design Concepts

The provided model provides an application of the Tragedy of the Commons dilemma to a model grocery store. The model provides insight into this example by portraying food as a common-pool resource. Since this resource is exhaustible, and psychological inputs such as perceived scarcity significantly influence consumption, the model can accurately simulate household and consumer consumption in a grocery store during the COVID-19 pandemic.

For emergence, unpredictable results do not necessarily originate from adaptive traits. However, model results do in fact fluctuate in unpredictable patterns, however, this is primarily due to multiple behavioral dispositions being changed that influence each other. All in all, the model is entirely dependent on inputs, and nothing else.

In terms of adaptation, agents in the model do not necessarily change behaviors based on themselves or their environment, other than the input variables. The psychological dispositions, and other input variables such as the food resupply rate, act as the sole determinant of agent behavior.

The objective of the model is to determine how perceived scarcity impacts consumer behavior during a pandemic, more specifically, if and when a Tragedy of the Commons occurs. To elaborate, if consumers believe that goods will be scarce in the future due to a pandemic, such as COVID-19, will those goods become exhausted where no consumer can provide the necessary amount of food needed for their household? If that is the case, how much time will be necessary to create that exhaustion?

Since agents do not change their behavior based on their prior experiences in this model, the concept of learning in the ODD framework does not apply.

In terms of predicting how the model will function, the model should act similarly to the original model by Julia Schindler. Additionally, however, the model should see dramatic consequences as a result of the modification of adding perceived scarcity and the unstandardized beta.

From a sensing perspective, the model uses a system of numerical reward for altering the behavior of agents as a result of the input variables. For example,

“reward-coop” is either a -1 or 1 value based on if a household acts in a way to be cooperative. After a slider variable is set, and a reward value is returned, the agent can sense what kind of behavior they should exhibit in consumption.

IV. Baseline Parameterization

Non-Focal Parameters (Remain constant throughout experiment)

Name	**Baseline Value**	**Description**
food-resupply-rate	0.008	regrowth rate of food
consumer-minimum-food-needed	1	annual forage requirement of consumers on patches
initial-supply-of-food	94	percent of patches covered in supplies at startup
cost-of-living-per-person	98	Cost of each consumer
total-consumers	314	total number of consumers at startup
total-households	6	total number of households at startup
learning-factor	0.74	how fast households react to a change
selfishness	1	how much a household values acting in a way that benefits themselves
cooperativeness	0	how much a household values acting in a way that benefits the group as a whole
fairness-to-myself	0	how much a household values being fair to themselves
fairness-to-others	0	how much a household values being fair to other

		households
positive-reciprocity	0	to what degree a households will react with positivity to other households acting positively
negative-reciprocity	0	to what degree a households will react with negativity to other households acting negatively
conformity	0	to what degree does a household value doing what the group has done in the past
risk-aversion	0	to what degree does a household prefer to take actions that reduce financial risk
maxcapacity	900	maximum number of consumers in the world (to simulate maximum capacity rules at stores during the pandemic)

Focal Parameters (Treatment variables, changed throughout scenarios)

Name	**Initial Value**	**Description**
perceived-scarcity	0	what consumers imagine scarcity will be like in the future term
unstandardized-beta-of-PS	0.76	for every increase in perceived scarcity, proportionally what impact will be had on shopping

		behavior?

Under baseline parameterization, a Tragedy of the Commons occurs at approximately 71.3 ticks, with a total number of consumers being approximately 742 at the time of the exhaustion of resources.

V. Discussion of Experimental Design

The question that I am asking with the Experimental Design that is attached, is that if perceived scarcity is increased, how will that impact the amount of time it would take for a Tragedy of the Commons to occur? I hypothesize that if perceived scarcity increases, the amount of ticks should decrease. However, I also expect there to be some unusual fluctuation in the data due to the unstandardized beta coefficient. This may cause ticks to increase at first instead of decreasing.

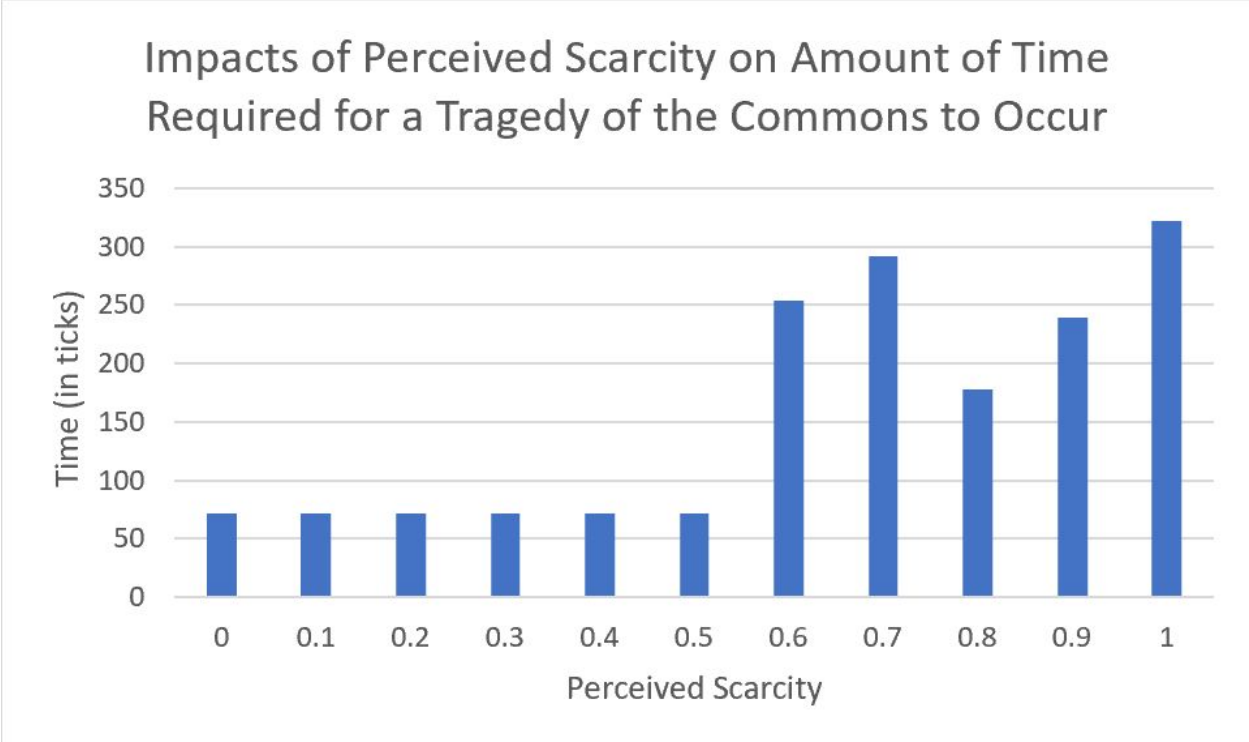
When considering the planning stage of the Experimental Design, it is important to note the significant modifications made from Schindler's original Tragedy of the Commons model. These include changing the stop procedure, which was originally set to stop at 300 ticks, and was changed to stop at either the exhaustion of the resource or at 3000 ticks, the latter as a backup method. The scenario was modified from originally representing G. Hardin's pasture example, to a model grocery store stocked with food. Additions also include perceived scarcity and its unstandardized beta, which provided a basis for this research.

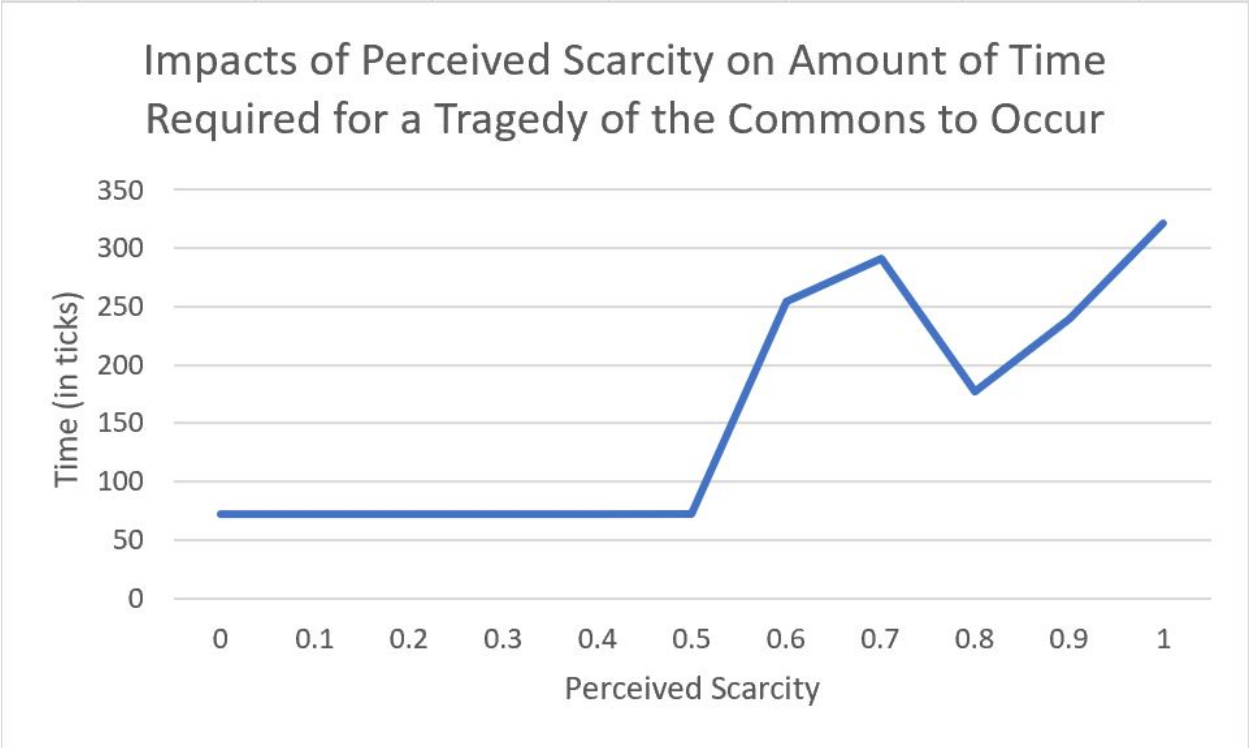
Randomness and replicability were also preserved in the Experimental Design, primarily by setting a random seed. This made things very simplistic and easy to follow,

especially since there was no exogenous input data, as this was a purely agent based model.

VI. Results

My findings significantly differed in some regard to my expectations in my hypothesis. In general, the output data proved to be much more sporadic than I had expected. After a certain threshold value of perceived scarcity, the variance in the data increased by a profound degree. My expectations did prove somewhat true, in the aspect that the amount of ticks increased before it decreased, however, the decrease was not as solidified, as the ticks value increased again afterward. The pattern of data is visualized in the following graphs:





As seen in the above graphs, perceived scarcity did increase at first. This threshold point is noticeable around the perceived scarcity value of 0.5. It is important to note that the 10th replicate of the 0.8 perceived scarcity value resulted in no Tragedy of the Commons to occur. This portrays what is also visible when looking at the data between replicates, in that the variance is extraordinary after perceived scarcity reaches 0.5.

VII. Conclusion

To conclude, the data met some of my expectations in terms of its pattern. However, the decline of ticks did not meet the significance I expected it to, as it increased again right afterward. The main difference between my findings and my expectations was the variance of the data after perceived scarcity reached a certain threshold. I would conclude that there may be another input playing a role, as this may

explain the threshold's existence and why the variance was so intense at these values. All in all, there is much more research that can be accomplished when it comes to perceived scarcity and the Tragedy of the Commons in this scenario.

References

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Schindler, Julia (2012). 'Rethinking the Tragedy of the Commons: The Integration of Socio-Psychological Dispositions', Journal of Artificial Societies and Social Simulation, 15 (1) 4. Retrieved Aug. 10, 2020, <http://jasss.soc.surrey.ac.uk/15/1/4.html>.
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