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Final Project Report

Civilization Model

Introduction

Throughout history great empires have risen and fallen constantly, torn apart by war, economic collapse, or social unrest. Yet at the peak of every empire, there lay a thriving economy, where production rivaled its neighbors and the economy evolved to best support the population and infrastructure. Economies tend to have a set level of willingness to spend; Some spend deep into the red while others save vast amounts of resources for difficult times. Efficient economies generally possess three important traits: a large workforce to collect resources, technology to increase the efficiency of the workforce, and trade to obtain less prevalent resources for more prevalent ones. While the most efficient economies possess all three of these traits, it is unclear as to how each one affects the economy individually, or which of three is most important. Some economies are able to thrive with only possessing two of the traits, while some manage to stay productive with only one. Along with this, the willingness to spend of many civilizations varies greatly over time, yet it's difficult to observe how this affects their economic growth. My model is designed to show a simplified economic view of civilizations and to test what the most efficient traits are for these civilizations to possess, along with checking how much of an impact frugality has on economic growth.

Overview

This model is designed to test the importance of workforce, machinery, and trade in creating a productive and efficient economy. While these are all very important, the goal of this model is to determine which is the most important, along with checking which two-trait

combinations create the most efficient models. This model is also designed to check how willingness to spend affects economic growth, by comparing civilizations with different levels of spending.

While this is a simplified model, it can show us important results about the traits of an efficient economy. While many of the greatest civilizations have had all 3 of these traits, smaller economies have been able to thrive while lacking one of these attributes. Isolated civilizations have been able to create thriving economies without trade, smaller civilizations have flourished despite lacking a strong workforce, and less advanced civilizations have prospered with underdeveloped technology. This model can help show which of these types of two-trait combinations has the greatest effect on productivity and which single trait will allow for an efficient economy. Showing this will allow us to potentially theorize on collapses of historical economies while also giving us the basis to hypothesize on the growth of developing economies.

The second part of this model is testing the importance of frugality on a growing economy. While this model won't show the benefit of frugality (as the test civilizations don't gain any benefits from saving resources), it is designed to show how much of a negative effect frugality has on an economy. These results will prove interesting in observing the current spending techniques of civilizations and using our findings on frugality to theorize on whether spending changes will have a positive or negative impact on economies.

Model Implementation: Setup

To begin my model, I set up two "islands" made of green patches with the size of the islands based on a slider in the interface. I randomly choose the location of 3 x 3 yellow, red, and dark green patches, to represent gold, food, and wood, with the number based on the

sliders in the interface. I also randomly choose the location for a “town center”, which is a 3 x 3 brown patch. I run this process for each island, with the result being two different looking islands with the same number of multicolored patches. All the patches that are not on the island are colored blue, and treated as “water”. There are red patches north of each island, designed to turn green when the island is “finished”, meaning all of the resource patches are gone (which I will explain more in depth later). This is shown in Figure 1. There are also 6 monitors set at 1000: food, wood, gold, food2, wood2, and gold2. These correspond to the amount of resources for each island, with the first 3 corresponding to the first island (left island) and the last 3 corresponding to the second island (right island).

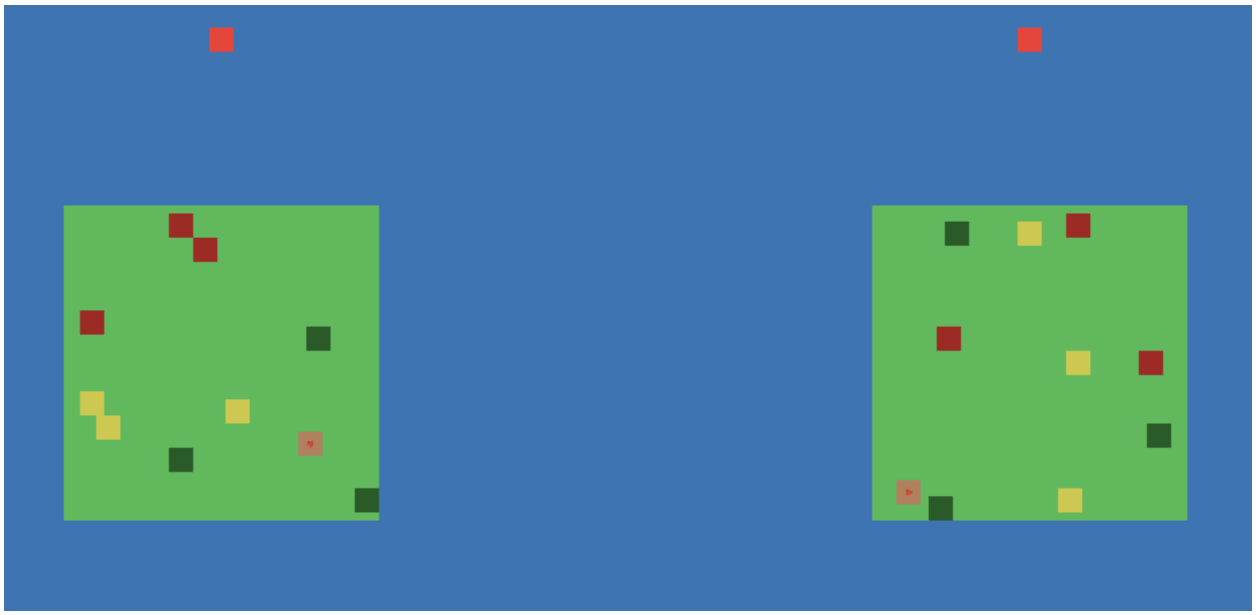

Figure 1: Island setup

There are also several turtles created on each town center for each island. These turtles are the “workers” and they consist of 3 different breeds: farmers (red), woodcutters (black), and miners (yellow). These turtles are designed to collect resources, with farmers

collecting food, woodcutters collecting wood, and miners collecting gold. All of this will take place after the go button is pressed, but this is the extent of the setup.

Model Implementation: Go

When the go button is pressed, the turtles begin to wander randomly. If they run into a water patch, they turn around and keep wandering, as shown in Figure 2.

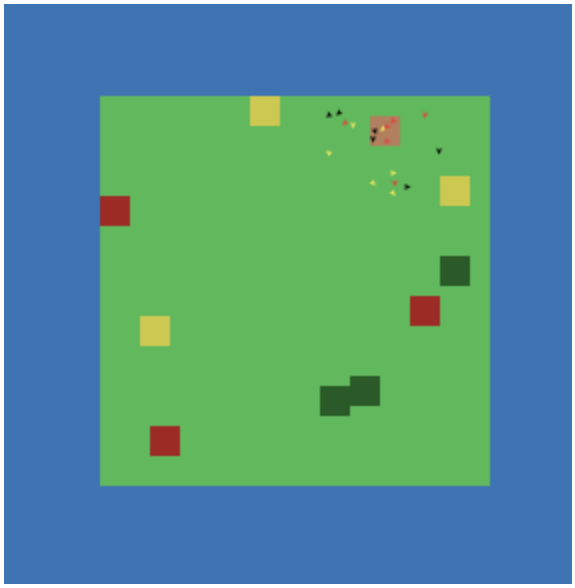

Figure 2: Turtles wandering

If they run into a resource patch, several things can happen: they can run in to a patch that they collect (i.e miners running in to a yellow patch), they can run into a patch that they don't collect (i.e miners running in to a red patch), or they can run into a patch that they don't collect while the correct workers are busy (busy meaning already collecting, which will be explained later). In the first circumstance, they set this patch as the destination patch and "collect" resources from it. The colored patches each have a "resource" variable set at 100,

while the workers all have a “resources” variable, which shows how much resource they have, along with a “maxresourcelevel” variable, which shows the maximum amount of a resource that they are able to collect. When a worker collects from a designated patch, the resource of the patch decreases by the maxresourcelevel of the worker while the resources of that worker increases by the same amount. Along with this, when the worker runs into this patch it calls all of the other designated workers to collect from this patch as well. Once a worker has collected from a patch, it goes back to the town center to deposit the resource which increases the specific global resource by however much resources the worker had and sets the workers resources to zero. This worker then goes back to the designated patch, and this continues until the resource of the patch reaches 0, in which case it disappears, and all of the workers collecting that resource begin to wander again. This tends to work similarly to the “Ants” model, where the turtles usually run into one of the other patches in the cluster (which is 3 x 3) and continue to do so until the entire patch is gone.

The second circumstance, when a worker runs into a patch that it isn’t able to collect from, it calls the appropriate workers to collect from the patch and continues to wander. In the third circumstance, when a worker runs into a patch that it isn’t able to collect from and the appropriate workers are busy collecting from another patch, the worker turns around, pretends like nothing happened, and continues to wander. These interactions are shown in Figure 3 and Figure 4. This is the main interaction behind the resource collection of this model.

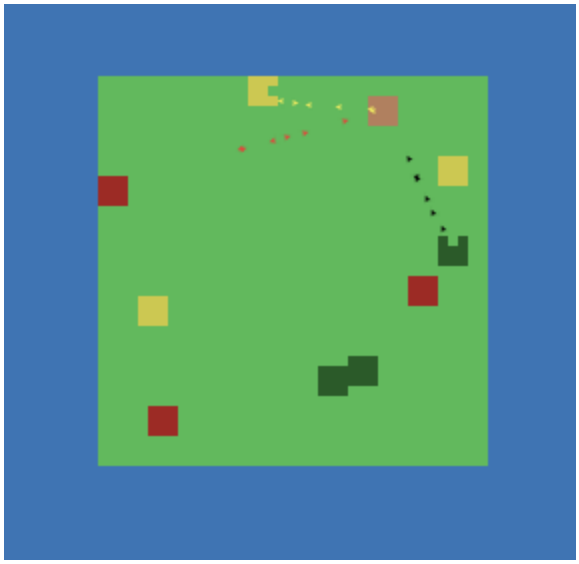

Figure 3: Early Collection

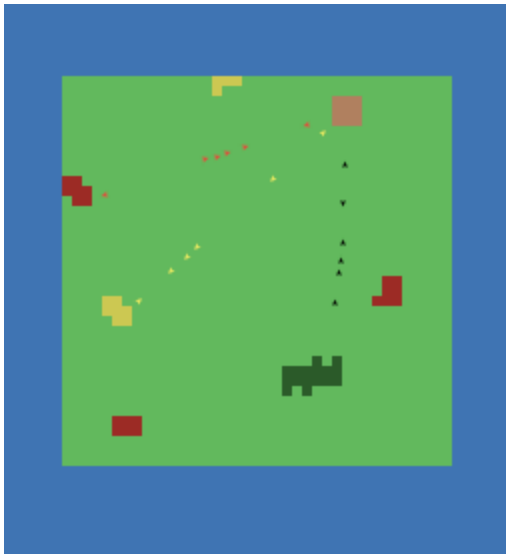

Figure 4: Later Collection

Model Implementation: Strategy

One of the two main points of this model was to test the importance of a strong workforce, machinery, and trade in an economy. These were classified as strategies, with some strategies being combinations of two of the others. The individual strategies will be explained below.

The first strategy is called “workers”, and this strategy is designed to represent a focus on expanding the workforce. After go is pressed, civilizations with this strategy check whether they have enough resources to create a worker (which costs 50 food), and if they do, then they create one. The decision on which type of worker to create comes from a weighting process, where each resource is given an equal initial weight, and when a worker corresponding to that resource is created, the weight of that resource decreases while the weight of the other resources increases. The decision on which worker to create is based on which resource has the greatest weight at that moment, and this technique creates a similar number of each type of worker, allowing for a diverse workforce. New workers behave in the

same way as old workers, and having more workers should allow a civilization to collect resources faster, therefore becoming more productive. This is shown in Figure 5.

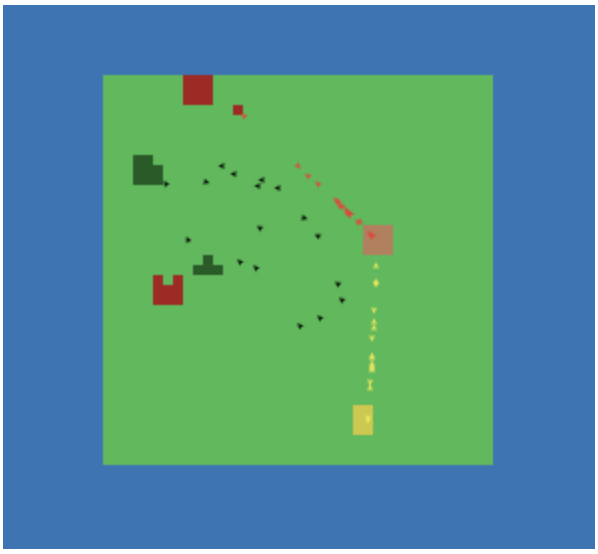

Figure 5: Workers Strategy

The second strategy is called “buildings”, and this strategy is designed to represent a focus on increasing technology and the efficiency of the workers that are already in the workforce. Civilizations with this strategy check to see if they have enough resources to create a building (which costs 300 wood) and create one if they do. The buildings each correspond to a type of worker (orange “forge” = miner, violet “farm” = farmer, turquoise “lumbermill” = woodcutter), and are designed to increase the efficiency of the workers, much like technology does. The method for this is when a building is built, it increases the maxresourcelevel of the corresponding worker, thus allowing those workers to collect more resources in a shorter amount of time. The type of building to be built also relies on the same weighting process as the increase of the workers does, which is important when the two

strategies are combined. Having workers with increased maxresourcelevel allows for faster collection of resources which should lead to higher productivity. This is shown in Figure 6.

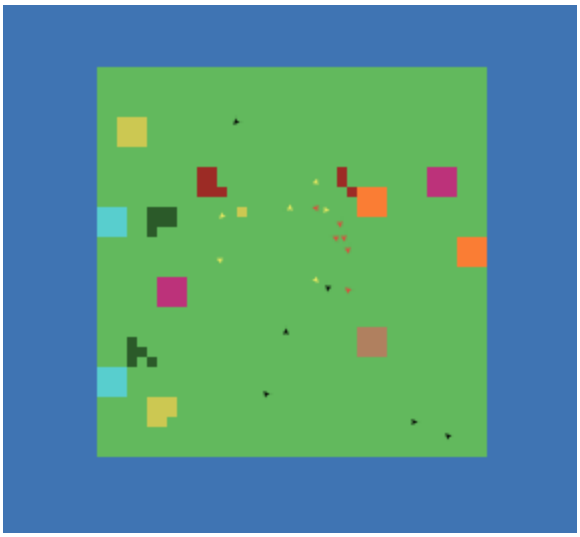

Figure 6: Buildings Strategy

The third strategy is called “trade”, and this strategy is designed to represent trade or common resources for more scarce resources. Civilizations with this strategy check to see if they have enough resources to build a dock (costs 800 gold) and create one if they can. Creating a dock also creates a boat which moves around the border of the island. When it leaves the dock, it takes 50 of the highest resource possessed by the civilization. When it returns to the dock, it brings back 50 of the lowest resource possessed by the civilization. If a civilization has multiple docks, it performs this every time it hits a dock, which is equivalent to doubling the trade. This is helpful in spreading around resources and allowing for variety in the economy, and should lead to more efficient economies. This strategy, however, would not be very productive if neither of the other two strategies were implemented, as is true in real

life; to have effective trade in an economy, you need a strong flow of resources and the ability to allocate new resources towards production. This is shown in Figure 7.

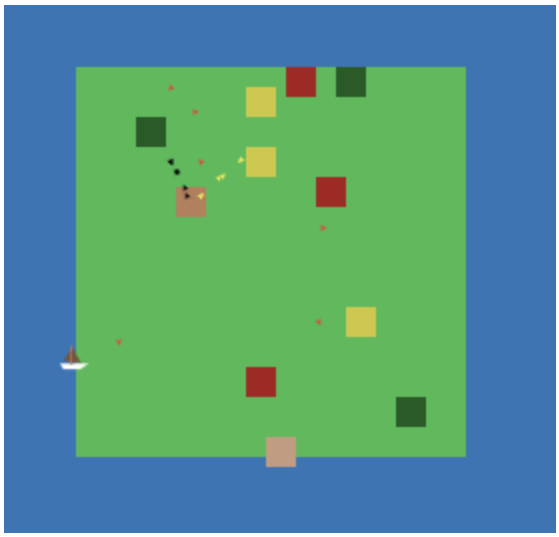

Figure 7: Trade Strategy

These are the three basic strategies, which are contained in all of the other strategies. Three of the choosable strategies use just one of these, three use a two strategy combination, and “neutralfocus” uses all 3 of the strategies. This is the extent of the strategy focus of the model. The neutralfocus strategy is shown in Figure 8.

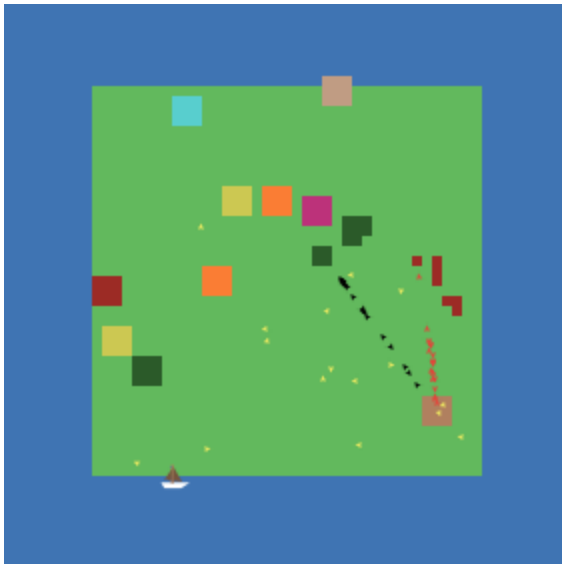

Figure 8: Neutralfocus Strategy

Model Implementation: Frugality

The other main focus of this model is to test how frugality affects an economy's growth. One important distinction to make is that in this model there is no benefit in saving resources, as there are no emergency situations that would require a store of resources. With this in mind, the model is not testing whether lower or higher frugality will increase efficiency because, based on the rules of the model, higher frugality offers no benefits. Rather this model is testing how much efficiency suffers when frugality is higher and whether it requires a large increase in frugality to impact productivity in a civilization. To test this, I have a "frugality" slider for the first island and a "frugality2" slider for the second island. This acts as a spending limit; the civilizations won't spend if it will put them under the frugality limit. This sets the same limit for all resources and is a hard limit, meaning under no circumstances will a resource drop below the frugality. This is a good way to test a civilizations willingness to spend and the model is designed to see how much of an impact frugality will have on productivity.

Model Analysis: Parameters

There are several parameters in place to test this model. There are monitors recording the resources of each civilization, along with the total resources of each civilization. The total resources monitors only factors in positive resource gain, to focus on income rather than profit, in order to not discourage spending. Included is a switch called “tprof” which includes trade income in the total resources but, again, only includes the positive resource changes. For tests, this switch remained off, since there is no net resource gain from trade and therefore this creates slightly misleading results. There is also a plot included which graphs the total resources of each civilization. There are several other sliders, which were used to set up the island, and can be altered to run different experiments.

The parameters that vary during testing are the strategy choosers and the frugality sliders. The strategies selected by the choosers will select which techniques are used by the civilizations when running their economy and the frugality sliders will set the frugality. To create an end condition, the red patches above the island will turn green when all of the resources on the island are gone. This is the way to find the most productive economy, as it will be able to collect all of the resources on the island the fastest. This is also better than using a resource level as an end condition, as certain strategies may take longer to develop than others, so this is equivalent to choosing the most productive economy by checking which is able to collect all the available resources the fastest.

Model Analysis: Strategy Test

To test the effectiveness of different strategies, I used the BehaviorSpace component of NetLogo. I ran 6 experiments: the first three ran thirty times each, with each individual test altering the strategy of the second island 3 times (between all of the individual technique strategies), and each test had the first island set to a different individual technique strategy. This way I was able to test each possible individual technique strategy combination 20 times (10 times for each island), which gave me a large amount of results. The next three also ran thirty times each with the same method, but this time compared two technique strategies. This also allowed me to get 20 results for each combination. Each run ended when one of the civilizations had collected all of the resources on its island and recorded which civilization ended the run. To figure out which strategy was most effective, I recorded how many times each strategy finished first during the twenty comparisons, thus showing which was the most productive and how much more productive it was.

Model Analysis: Strategy Test Results

The results for the strategy tests are below, with W signifying the workers strategy, B signifying the buildings strategy, T signifying the trade strategy, and 2 letter combinations representing two technique combinations of strategies. Percentages indicate how many times that strategy finished first compared to the one it was tested against and each test was run twenty times.

W	B	W	T	B	T	WB	BT	WB	WT	WT	BT
75%	25%	100%	0%	100%	0%	100%	0%	85%	15%	100%	0%

Looking at this table, several conclusions can be reached. With the single technique tests, the important test is W vs B, as the design of the trade strategy made it less likely to succeed without any other strategies (this is explained more in the paragraph after Figure 6). This result shows the importance of a strong workforce, although there is a clear benefit to having advanced technology. The more important results are the comparisons between the two technique strategies, as most economies have at least two of the techniques in order to obtain some level of efficiency. This also showed the importance of a strong workforce, along with the secondary importance of technology. The trade technique showed some success, however it was overshadowed by the other two, potentially due to the simplification of the model. Trade is generally most effective when certain resources are unavailable, and in a situation where all resources are available, it could become less important. Overall, this model showed the importance of a strong workforce and that advanced technology also plays a large role in economic productivity.

Model Analysis: Frugality Test

To test the effectiveness of different levels of frugality, I used BehaviorSpace to create two experiments. Both civilizations were set to the “neutralfocus” strategy, which implements all three economic techniques, and is the most productive setting. They both ran 60 times, comparing the frugality of one island (set at a default value of 200) against the frugality of the other island which was incremented from 0 to 1000, by 200, every 10 runs. One test altered the frugality of the first island and the other altered the frugality of the second island. I used the same productivity measure as I did in the strategy test, checking which civilization

collected all available resources first, and recording how many times each happened over the twenty results for each comparison.

Model Analysis: Frugality Test Results

The results of the frugality tests are below, with the numbers indicating the set level of frugality (where the civilization could not spend below that amount), and the percentages indicate how many time that level of frugality finished before the one it was compared against (all tests were run twenty times).

200	0	200	400	200	600	200	800	200	1000
25%	75%	55%	45%	65%	35%	90%	10%	85%	15%

These results show the expected result: that as frugality goes up, efficiency goes down. This is expected because the model isn't designed to show the benefit of frugality (as explained in the paragraph before "setup"), but to show how much increasing frugality lowers the productivity of these simplified economies. The results show that slightly increasing frugality doesn't affect efficiency too much, but rather increases it semi-linearly, until it reaches a large difference between frugalities. I'd expect over the next few increases in frugality for the finishing percentage of 200 to reach 100% based on these results, and this shows the impact that frugality has on an efficient economy.

Conclusion

The first part of my model shows the importance of a strong and large workforce when establishing an efficient economy. This is a vital component to a productive economy, and shows why almost all of the great civilizations in the world have had a large workforce in order to maintain the their economic power. The model also shows the importance of technology which, when paired with a powerful workforce, can set the foundation for a robust economy. The model shows a lack of importance of trade, which doesn't imply that trade is not important, but signifies that establishing a powerful economy is generally a step that comes before trade can be truly effective.

The second part of my model shows the importance of spending in order to grow a thriving economy. While this model does leave out important benefits of saving money, it shows an important point: growing an economy requires investment into that economy and spending money can help create an efficient and powerful economy.

Both these parts show important and interesting results on the growth of economies. If I could expand this model, I would create interaction between the civilizations, which would perhaps add more depth to the trading strategy. I would also create benefits to frugality, which would allow for a more in depth comparison between spending and saving.

Simplifying an entire civilization is bound to create generalizations, but this model creates simple and logical results based on general rules of economic production. The current model shows a simplified view on one of the most complicated aspects of any civilization, and the results of these tests are logically and historically sensible. Hopefully this model can be used to show important trends among economies, to explain the rises and falls of historical civilizations, and to predict what the economic future has in store for us.