How a given society's criminal activity is influenced by police policy

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Abstract

This paper argues how a given society's criminal activities are influenced by police policies(tax rate and police salary). The model allows user to set the features of a society, including living expense, job ratio, fair factor and tendency to change career. This paper argues the rules for of each people in a society and explain why the rules are reasonable. Then it shows how the two policies influence wealth distribution and career distribution and furthermore explain why the influence makes sense. Basically there exist a "turning point" for police pay and tax rate. If the police pay is lower than this point, the higher the better, if it is higher than this point, the higher the worse, but the speed of becoming worse decreases over time. However there is no universal rule to define a police pay as it is demonstrated in this paper that same police pay can behave very differently under different society. The same basically holds for tax rate. Then this paper explores three extensions. Firstly, this paper explores what if thief has chance to escape from police. Thieves are tend to form a flock in this case. Secondly this paper argues how catastrophe influents a given society. In catastrophe mode, the collective wealth of the whole society decrease, but in certain kinds of society the population surprisingly becomes larger. Last but not least, this paper shows how to make a corresponding HubNet model.

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1. Introduction

Currently, lots of researches have been done of the relationship between police and criminal, how crime rate varies under different society, the relationship between tax rate and society productivity, how disaster influences society. However, few of them put the story as a whole. This paper wants to show how a given society's stability and productivity are influenced by certain polices, those are: tax rate, police salary, living expense and people's tendency of changing career. This is a very comprehensive thus tough issue so this paper abstract the society as simple as possible and only focus the most significant factors (but it is still very complex).

Here is a brief overview of the whole paper. Section 2 illustrates the assumption and definitions of the model. Section 3 shows how agents and the system as a whole behave by defining the detailed rules of agents and argues why the reasonable. Section 4 analyzes the output of model, that is, showing how different polices lead to different interesting results using behavior space. Section 5 illustrates two model extension: making the thieves become smart who has chance escape from police and introduce disaster to the society to see what kind of society can survive in the condition of disaster can happen. Also, analyze of the extension happens here. Section 6 illustrates HubNet extension, and shows how human player behave different from the model's rule, as along the different results which are very interesting. Section 7 analyze the strength and weakness of this model and the potential improve outlook. Section 8 posts some further work. The last two sections are acknowledgment and references.

Lastly it should be noted that although there is no a separated section discuss model validation, each section analyzes the corresponding reasons which are in fact validation of the model.

2. Definitions and assumptions

This section illustrates definitions, parameters and assumptions of the model. The purpose is to keep user or reader on the same page with author.

2.1 Definitions

The definitions are some terms used in this paper which may have different meanings from their universal meaning, or what certain terms mean in this model's context.

- Collective wealth
  When we use this term, it means the total amount of money of all people.
- Career and Job
  This two terms are different from daily use. In this model, career means the breed of turtle and job means the patch which has job salary. So by "change job" means a worker leave his current patch and try to move to another patch. By "change career" means an individual change its breed.
- Job ratio

This is a parameter user needs to set. It is the ratio of the patches with job to all patches. The higher this number, the more jobs in the world, and the easier people can find job.

2.2 Classification of input parameters

The input parameters of this model can be divided into two parts roughly: the setting of a society(initial population of each breed, job ratio, fair factor, people's tendency of changing career) and the policies of the society(police pay and tax rate).

Regarding of the setting of a society:

- number-of-worker, number-of-thief-number-of-police
  As their name implies, they are the initial population of each character. These parameters have to be set before running "set up" procedure. Changing them after press "go" button has no effect.
- job-ratio
  The higher this value, the more jobs in the world.
- fair-factor
  The higher this value, the more fairly salary is distributed.
- living expense
  The basic living expense that everyone needs to spend each tick.
- career-change-tendency
  The probability for everyone to change their career.

Regarding of the policies

- police-pay
  The salary police expects to get each tick. But police has no guarantee to get this salary unless government collects enough tax
- tax-rate
  The ratio needs to take away from worker's salary. Tax rate is used for paying police.

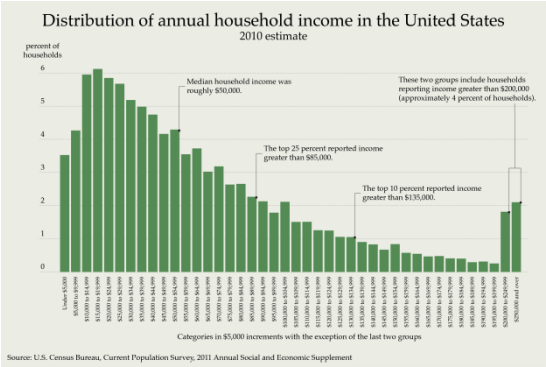
2.3 Assumptions

Any model needs certain assumptions because things in model varies from in real life more or less. Here shows certain main assumptions and explain why the model can abstract real world in this way. Some other assumptions are related to certain specific rule, so will explain right under the rule(section 4). Note that if some assumptions are illustrated here, rest part of the paper just use the assumptions as facts.

- There are three kinds of careers in a society
  In real life obviously there are numerous kinds of careers. However we roughly divide all kinds of careers into three categories. Worker: those who really produce wealth; Thief: those who do not work themselves but try to grab wealth from others. Note it does not only map thief in real life, also map all those who take advantage other labor. Police:

government people who take tax and try to punish thief or contribute other things to society. So we can abstract our model using three types of turtles.

- Everyone wants to improve his collective wealth as much as possible.
  In real life some people does not care wealth much or even prefer poor life, however for the purpose of this model, we assume everyone wants more wealth to avoid dying.
- The salary of jobs obey Boltzmann distribution
  According to the statistics of salary, almost in all society the distribution looks like Boltzmann distribution except the population with highest income. Like figure:



  But for the purpose of this model, simply ignore the last part and assume it is absolutely obey Boltzmann distribution.
- Tax rate is linear of salary and paying police is tax's only use
  This assumption is safe for the purpose of this model because this can guarantee the higher one's salary is, the more he contributes to society. And after paying tax, the relative richer or poorer relationship between worker will not change. Secondly, since police here actually represents the government power, so tax only uses for paying police makes sense, if we ignore the welfare. In fact welfare is another police which can influence criminal activity, however this model does not cover it. So for this model's purpose we can ignore other use of tax.
- The living expense is the same for everyone
  In real life one's living expense is related to one's income. Higher income leads to higher living expense. However when set living expense linear with income, I find all the other output is roughly the same compared with simply setting a constant living expense. So for simplicity I ignore this factor. It makes sense though, become one can think living expense is reduced from salary, all people reduce some percentage of salary, the relative salary doesn't change. So we can regard the living expense here as the basic living expense which everyone needs to keep alive.
- There is no travelling fee when one moves
  One may think travelling fee is necessary because when worker find a job he will not move, while thief and police moves(see section 4 for detailed rules). So no travelling fee

looks unfair for worker. However I find the model output is the basically the same with or without travelling fee. The explanation would be since thief and police does not produce wealth, they will consume their wealth over time anyway, we can simply regard living expense cover travelling fee.

- One has chance to change job or career and income is the only reason.
  Due to my research of why people change career, there are multiple reasons:

Reason	Percentage(%)
The downsizing or the restructuring of an organization	54
New challenges or opportunities that arise	30
Poor or ineffective leadership	25
Having a poor relationship with a managers	22
For the improvement of a better work/life balance	21
Contributions are not being recognized	21
For better compensation and benefits	18
For better alignment with personal and organizational values	17
Personal strengths and capabilities are not a good fit with an organization	16
The financial instability of an organization	13
An organization relocated	12

  The reason can be divided by three groups: psychology reason, social reason and economical reason. Regarding all psychology and social reasons, we can simply simulate those by a random chance. By economical reasons, my idea is: If someone find other career has higher income, he has a chance take that career. This chance simulate something like they have ability to do the job, or they change career successfully.

3. Definition and explanation of Agent and system rules

This section shows how agents and the system as a whole behave by defining the detailed rules of agents and argues their rationale.

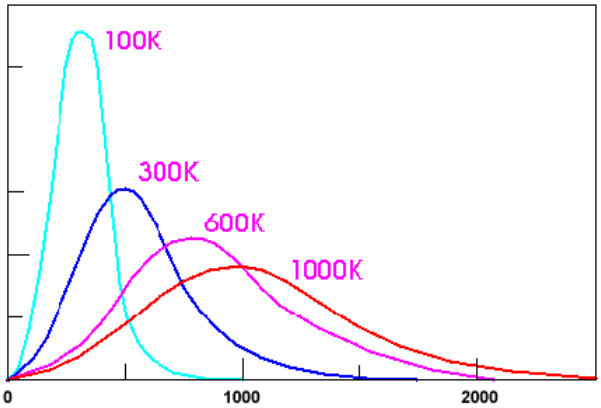
3.1 What is patch

Patches represent jobs in the model. Worker can get money from patches constantly. Based on the assumption in section 3, the salary each patch offers obey Boltzmann distribution:

$$f(v) = \sqrt{\left(\frac{m}{2\pi kT}\right)^3} 4\pi v^2 \exp\left(\frac{-mv^2}{2kT}\right).$$

This formula is usually in physics, but we can take advantage of this distribution. Here k is Boltzmann constant, which is 1.38e-23, m should also be constant, we set it as 2.18e-25, which is

commonly used. T is fair factor which is user input. This parameter is important because it means how "fair" the society is, as is shown below.



T decide the shape of distribution, when T becomes bigger, the salary distribution is more fair.

It should be pointed out that the area of the curve covers will becomes smaller when it is more smooth. In this model, it means for a more fair society, the sum of job salary is less. Whether this statement true is a very complex issue and beyond the topic of this paper. But it is suggested that when experiment with this model, if user wants to set higher fair factor, he should set lower living expense as compensate(user can set opposite way to do mental experiment though).

3.2 Turtle types and rules

As in the assumption section shows, the model has three types of turtles: worker, police and thief. Here is their rules and rationale of the rules.

If I am a worker:

- If my salary is enough for living, I will work here and get money, then I pay tax
  Rationale: In real life, when people change job or even career, they normally will not change one with much lower income. So we can assume they will not change at all because we only want to focus on their income. And tax is the big source of income of police, which is a main parameter of income, worker needs to pay tax to support police just as in real life people pay tax to support government. To simplify, the model set tax rate is linear with income. This does not hurt any result of model because the relative salary of each worker remain the same.
- Otherwise I will search job, I keep moving until I find a patch without anyone else
  Rationale: Since we use patch representing a single job, multiple worker on a single job doesn't make sense in real life. So worker needs to keep searching if a searched job is occupied by others. Furthermore, if cancel this rule, with proper parameters there will form certain cliques and everyone work on the jobs has highest salary, no one change

career and collective wealth of the whole society goes exponentially, this result does not help to analyze the topic.

- If my salary is lower than living expense, I will become a thief
- Otherwise I have 70% chance to change job and 30% to change career.
- If I choose to change career, first if my job salary lower than police pay, I will become police
- Otherwise if average worker wealth is lower than average thief wealth, I will become thief.

  Rationale: The above four rules can be regarded a big rule of changing career. These rules are somewhat complicated and are decided after experimenting the model for a long time. For the first rule, it is the condition that worker becomes a thief directly. This maps real world situation, if someone cannot support his life by working, he will choose to depend on others, either become beggar or thief, or some other career can grab money from others.

  The second rule guarantee worker has higher chance to change job than change career. Because in real life when people wants to improve income, they first try to change a work that is similar to his old one rather than a pretty different kind of work. In this model, as is stated in definition, job means all kinds of job and career means quite different work so worker has higher chance to change job. From many times of experiment, how higher this chance is does not matter much to the result we care as long as it is higher and not extremely higher. So we set it as a constant number(70%)to make the model as succinct as possible.

  The last two rules are about how to decide which career to change to. The idea is to compare the expectation of income of each characters. We hope to compare income per tick which is more important than collect wealth(someone is rich may be because he has low salary for a pretty long time, so income per tick makes more sense). However, thief has no stable income per tick, we only know their collective wealth. So the worker first compare job salary and police pay, if police pay is promising, he becomes police. Otherwise he compares the average wealth of worker and thief and choose the higher one. Since average collective wealth is the only information worker can take advantage in this case, which is not a precise estimation, so avoid taking risk, worker first consider becoming police then thief.

If I am a police:

- I first see if there is some thief around me, if so, punish him by taking half of his money

  Rationale: The first thing everyone wants to do is to collect wealth. But why take half of the thief's money? Intuitively, take all his money will lead him die immediately which implies kill the thief. In real world thief get punished to some degree but not killed.

Between 30% to 70%, which is reasonable range, there is no big different regarding output, so we can simply set it to 50% and do not bother user set this parameter.

- Then I walk around
  Rationale: The police is supposed to find thief. In fact for each individual, the chance it catch thief when it keeps still and walks around will be the same if thief is moving constantly. This is also same for true. But if we set them keeping still, everyone will be still and they never meet. So we need to let them go constantly.
- Then I have chance to change my career: If I find a job with higher salary than police pay, I become a worker and work here.
- Otherwise I check average worker wealth and average thief wealth, I will become the higher one if it is also higher than police pay.
  Rationale: The rules for police changing roles are also complicated. First of all, if a police happens to find a job with higher salary, he can simply become worker and take this job, because his life will improve for sure. Otherwise, it compares his own collective wealth with the average wealth of worker and thief, if his own wealth is actually higher, there is no reason to change career then. Otherwise he will choose the one with higher average wealth.

If I am a thief:

- I first see if there is some worker around me, if so, grab half of his money
  Rationale: The reason is similar to police. I try to set this as a parameter and find take much more than half will cause the population decrease quickly if there are lots of thief. This is not true in real world too. On the other hand, if take only a small part the thief is too poor to keep alive. Between 40% to 60%, which is reasonable range, there is no big different regarding output, so we can simply set it to 50%.
- Then I walk around
  Rationale: Like the police, nothing to do in this patch, just walk. Thief hope to find worker.
- Then I have chance to change my career if my money is less than average wealth of worker of police. If I decide change career, I will become the one with higher average wealth.
- Rationale: The rules for thief's changing career is relatively simpler. Since thief has no a stable job or stable income per tick, he has only one option: compare the average collective wealth over time. Thief will change career only when he finds others has better expectation. And when he chooses career, he will choose the one with higher average wealth because he wants to improve his life as much as possible.

3.3 System rules

There is one rule for the society as a whole: when everyone dies, the system stops.

Since the model wants to show career and wealth distribution over time under different policies, if there is some individuals alive, we can watch the information. Otherwise we can stop the model to claim the polices leads to a terrible result that the society is destroyed.

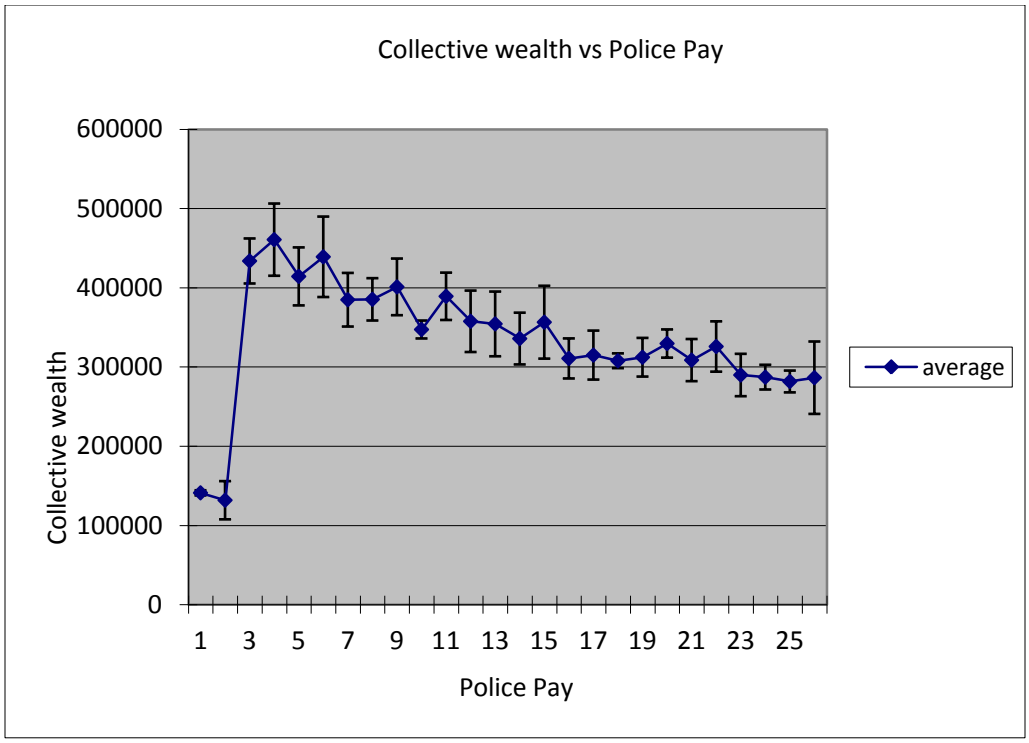
4. Analyzing model

This section analyze how police and tax rate influence career distribution and wealth distribution of a given society using behavior space. When run behavior space, we will stop model either everyone dies or up to 150 ticks. Because 150 ticks is enough to observe pattern and longer time such as 300 ticks, some societies will die so when cannot compare them. For all cases we set number-of-worker 250, both number-of-thief and number-of-police 0, so this will restated later. We will also look how same polices behave differently in different given society, a society can be set in lots of ways (we have seven parameters of setting society so this paper can hardly cover all stuff), so we just discuss several typical cases.

4.1 Analyze how police pay matters

We choose two very different cases to analyze how police pay influences career distribution and wealth distribution. Because one case may lead us to bias conclusion and restricted by length of article we cannot analyze all kinds of society. So we assume if something is true for two very different society, it implies the conclusion is independent of society, then it will be true in general.

Case one: job-ratio 70, fair-factor 0.1,living expense 1,tax-rate 0.10,career-chang-tendency 0.7, turn off thief-escape and catastrophe mode. Set behavior variables as ["police-pay" [0 2 50]] and repetition 10 times. Now running the model ten times and observe the collective wealth of the whole society:



From this statistical data we can conclude:

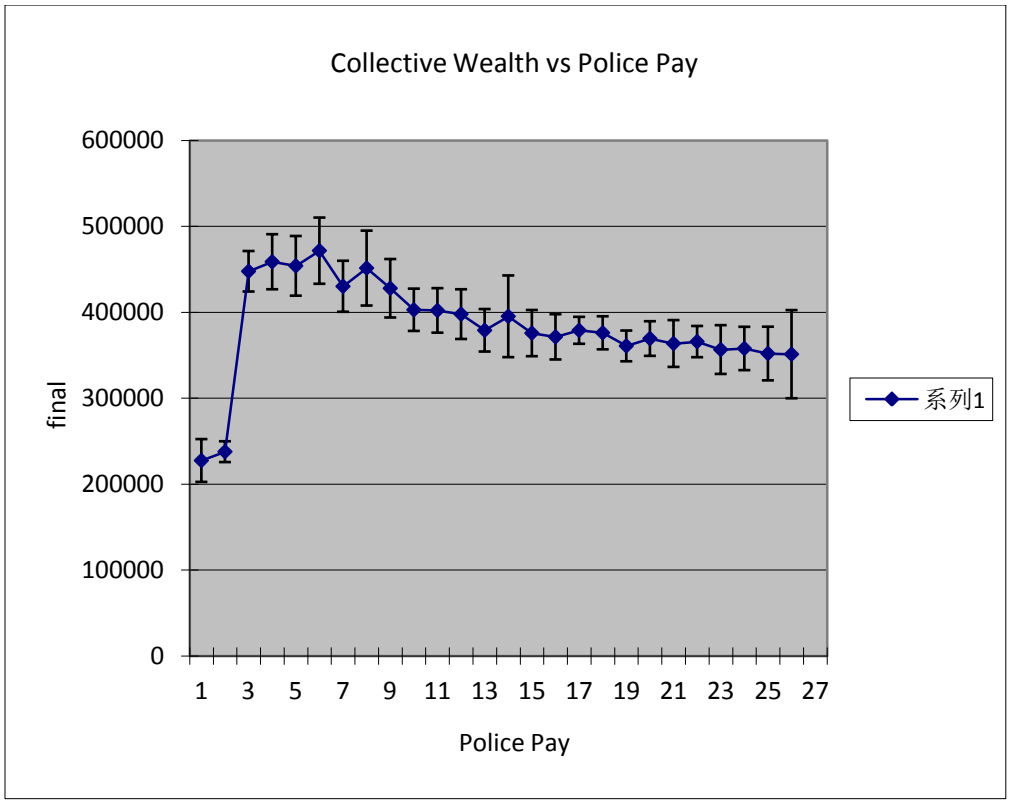
- The worst case is police pay is zero.
  This is because in a world without place, thief get no punished so it becomes more attractive. More worker becomes thief so less people are really producing wealth. Finally, the collective wealth is not good as others. However it should be pointed out that the society can still survive in a society without police.
- When police pay is higher than some value(6 in this case), higher police pay leads to worse result.
  This is surprising because intuitively higher police pay leads more people tend to become police so world is more peaceful so as more productivity. In fact, when police pay is higher which tax rate remain the same, government cannot afford paying police. So lots of people become police because the promising payment, however, they have little chance to get the money. This leads to they become poorer than before thus want to change their career if have chance to. This process leads to people switch career more often which will result in lower productivity than a society with same ratio of each career while people do not change career often. The reason is simple, in second kind of society people have longer working time.
- But the result tend to be stable. Means the speed become worse decrease and to some point it is almost still.

The reason is over some points, for example in this case 10, government cannot afford police no matter how much police pay is as long as it higher than 10. So the result will not change much over this point.

- The standard derivation is independent of police pay.
  First of all, notice the standard derivation is not small, this is understandable because one society is consist of lots of randomness factor, so the result may varies time to time.

Case two: change job-ratio to 30, fair factor to 4.3, career-change-tendency 30,.

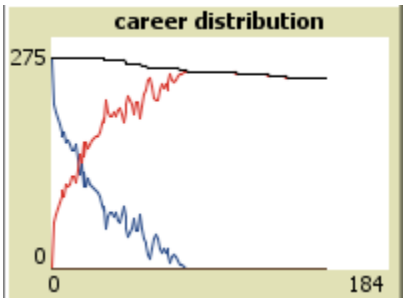
This case is different in the sense that the job ratio is much lower which salary is distributed very fair, and people are much less likely to change their career. Running this case ten times and we get the similar result:



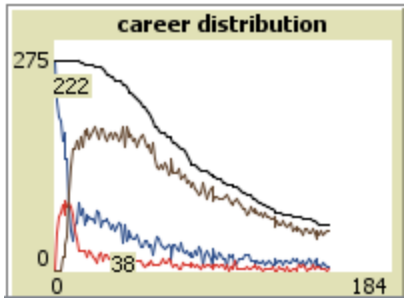
All the above conclusions hold thus verify our model indirectly.

Now we want to analyze how police pay influence career distribution. We set the society as first case.

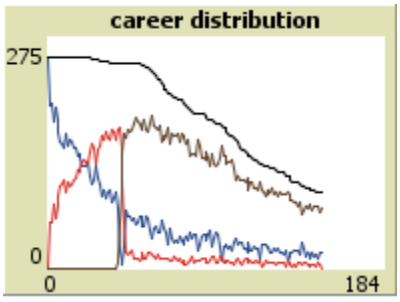
We run the model for times and set police pay 0, 2, 4, 6 respectively. The results are:



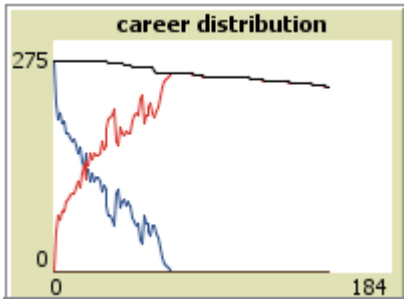
police-pay is 0



police-pay is 2



police pay is 4



police pay is 6

When police pay is zero, no one has incentive to become police, so lots of people become thief and they grab money from worker makes worker poorer and poorer finally die.

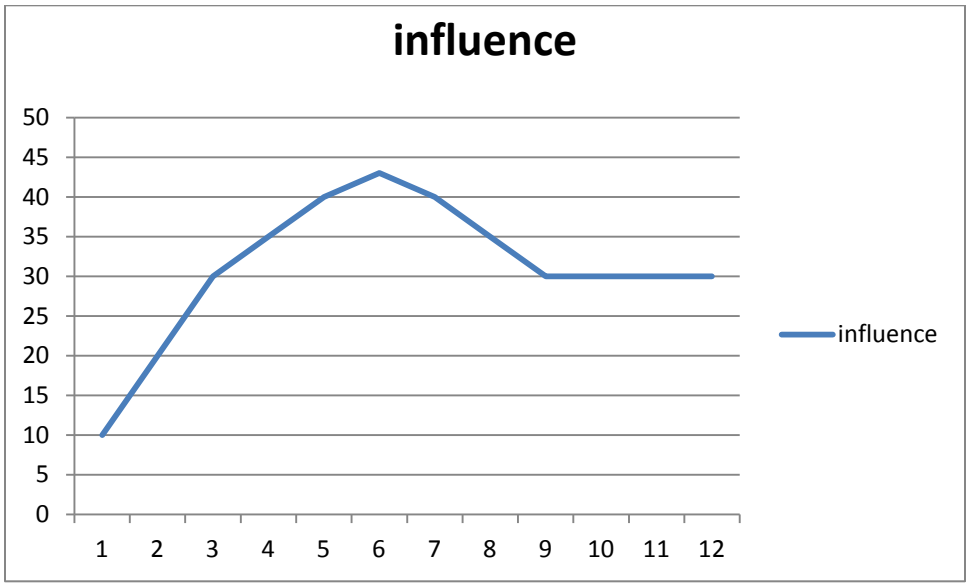
When police pay is 2, many people become police thus to punish thief. The interesting thing is this society has little thief while the whole population decrease a lot. This is a more promising situation than the first case. One can imagine run system longer in first case everyone is likely to die because they all thief while in this case more people are working thus leads to higher collective wealth.

When police pay is 4, at early stage there is no police because tax is not enough to pay for police. When people is attracted by the high police pay thus become police, they cannot get the money as promised, so they tend to change back. At the middle stage government has enough tax to pay for police, the situation becomes as similar as the second case.

When police pay is 6, interestingly the situation is like first case when police pay is zero. The reason is in this case government cannot afford police before working's dying out. In fact, set the police higher, the result will the same because government cannot afford police if police pay is higher than some value.

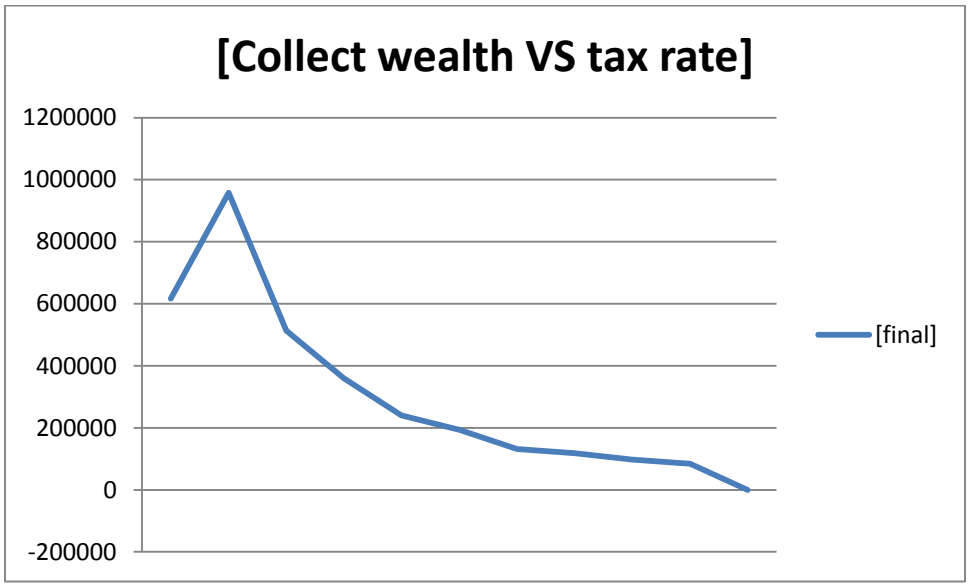
The study of how police pay influence of career distribution is perfectly match the study of how it influence collective wealth. On both side we can claim for a given society, there is a given point for police pay, less than this point, the more the better, over this point, the more the worse,

but the speed of becoming worse decrease and will reach almost zero finally. We visualize this statement as below:



4.2 Analyze how tax rate matters

Case one: set job-ratio 100, fair-factor 1, living expense 2,career-change-tendency 70,police pay 4. Watch tax-rate from 0 to 1 each time increase 0.1. We get the following result:



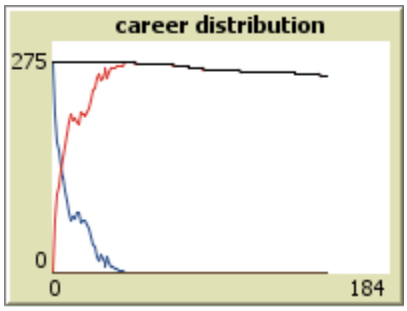
From these two results we can conclude:

- When tax rate increase, collective wealth first increase and to some point decrease dramatically.
  This is easy to explain because one can imagine if tax rate is low, government cannot afford paying police so thieves get no punishment and survive longer, which means less

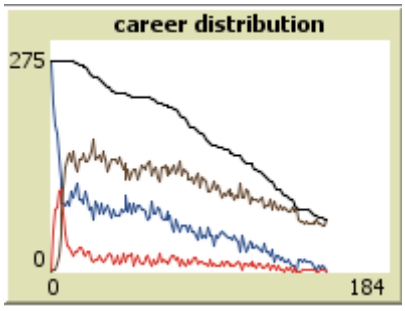
people really produce wealth. On the other hand, if tax rate is too high, government collect more money than it really needs, this part of wealth is like waste.

- But the decrease speed also decreases.
  Observing the model find it is because high tax rate leads government has store lots of money, after a while, this amount of money can afford police pay even everyone becomes police. So everyone tends to become police and no one produce, living expense is the same. We know that collective wealth=produced wealth - living expense. That is to say, after some point, collective wealth decrease in constant speed. So the only difference is the higher tax rate, the earlier this point comes. Overall there is no apparent difference if running system for a long time.

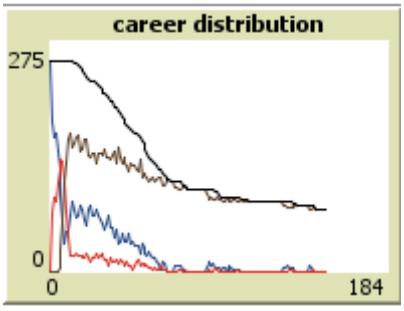
Now we want to analyze how tax rate influence career distribution. Using the same society settings and running the system for 150 ticks. Set tax rate as 0,0.1,0.2,0.3,0.9,1.0.



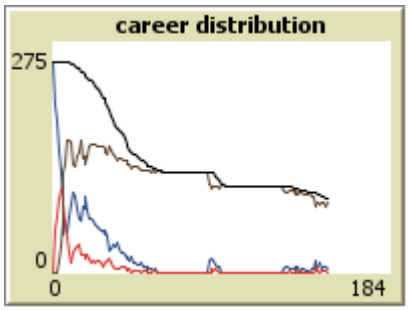
tax-rate is 0.0



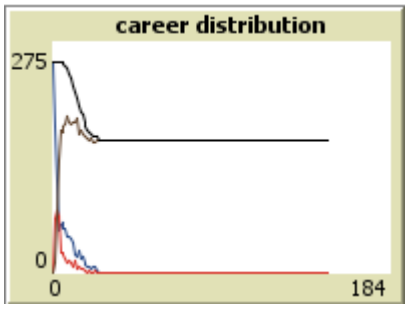
tax-rate is 0.1



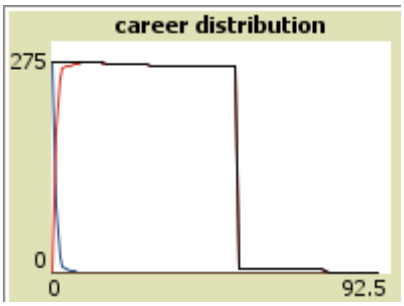
tax-rate is 0.2



tax-rate is 0.3



tax-rate is 0.9



tax-rate is 1.0

As is seen, tax rate has complex influence of career distribution.

When tax-rate is 0, government cannot afford police. Some people change to police due to promising police pay, however they will change back soon because they cannot get the money in fact. So thief has no chance to be punished. That is why the amount of thief increase dramatically in early stage, even everyone becomes a thief.

When tax-rate is 0.1, police will appear thus thief get punished soon. The subtle part is police will not appear immediately. It takes on average 10 ticks for police to appear. It is because it takes government a while to collect the money which can afford police.

When tax-rate ranges from 0.2 to 0.9, there is no apparent difference of final career distribution, almost everyone becomes police. There is still a subtle difference, when tax rate becomes higher, the situation everyone becomes police comes earlier, and fewer people will change to other careers. This is because when tax rate becomes higher, government can collect money faster, thus in the situation of police pay is high(recall that we set it to 4), everyone wants to become police and they can get paid.

When tax-rate is 1, people has no money to cover living expense, so they become thief. Nobody work leads all thief die quickly(normally within 100 ticks).

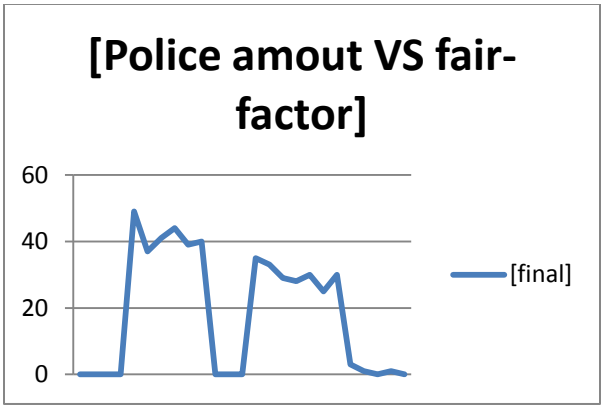
4.3 Analyze how same polices behave differently in different given society

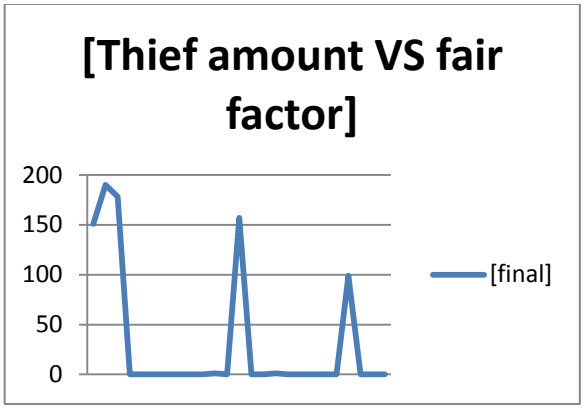
Again, society can be set in almost numerous way, so restricted by pages here will only analyze several typical factors.

To begin with, see an easy example which can show different society can leads same polices behave differently. we can compare the two cases in section 5.1. We have this obvious finding:

- In case 2, the curve is more smooth and the slope is lower than it is in case 1, and also its standard derivation is smaller.
  This is easy to explain, because in case 2 salary is distributed more fair and people are more reluctant to change career. So in this kind of society every situation are less fluctuant.

Then we using behave space analyze fair factor. We set the police pay as 3, tax rate 0.25, living expense 2, career-change-tendency 70. The result population of police and thief is:





Regarding police amount and thief amount under different fair factor, we can conclude:

- In the case police amount is large, thief amount is small.
  Running the model will find at some point, police has chance to appear or not. If they appear then majority become police. Otherwise, thief will be the majority of population. It is like which role conquers the world. Because in the case of one roles die out, the

collective wealth of that role becomes zero, when other roles wants to change career it is less likely to become that role. So once some role die out, it is hardly to reappear.

- For some point they result will change dramatically.
  These points are so called tipping point. When salary distribution changes a little, who conquers the world suddenly becomes opposite way. So far I cannot think of or refer to any previous research talks about it.

Regarding worker amount, it is always less than 10 nearly in all cases. The reason is when either police or thief conquers the world, each individual has the trend to become that role. And worker seldom gets chance to conquer the world because worker cannot get money from somebody else thus leads that person to die.

5. Model extension: thief escape mode and catastrophe mode

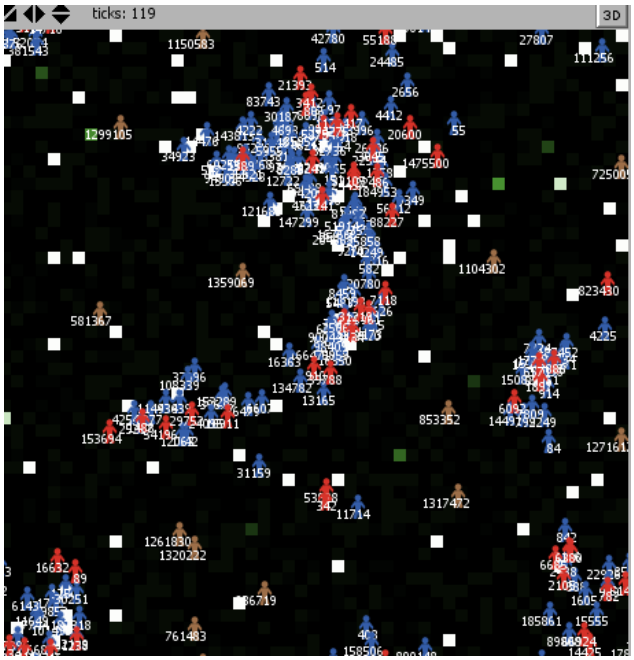
This section will show two interesting extensions: thief is smart to escape from police and introduce catastrophe to society. Regarding for analysis, this paper only state why certain extension result certain results rather than make the behavior space analyze. Because this is not the very core part of the model and not directly related to the topic of this paper.

5.1 Thief escape mode

This extension makes the thief has chance to escape from police. The rule is: if I see a police, I have a chance to escape punishing by turn back to police and move 2 steps away. The rationale is simple: in real life it is always hard to catch thief, and when thief escapes they choose opposite direction towards police.

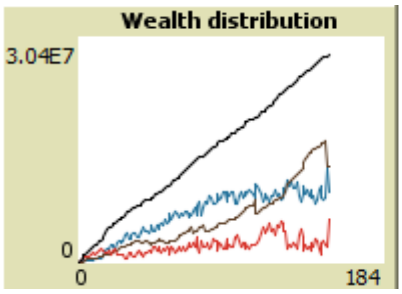
5.2 Analyze thief escape mode

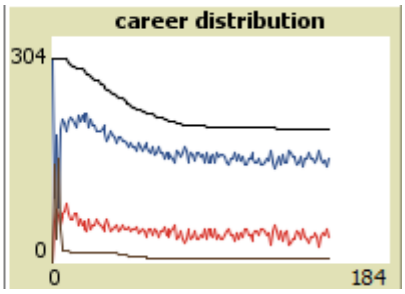
In a given society and policies(set parameters as: number of worker 276, job-ratio 40, fair-factor 0.1, living expense 1, career-change-tendency 72; tax rate 0.05, police-pay 4; but note that the following result are almost true for any given reasonable society and policies), then turn on the thief mode and set the thief vision to 8. Run the model till 150 ticks. We will see interesting phenomenon: people is like forming a flock, furthermore, the flock always happen in a area with several highest salary, as is shown below.



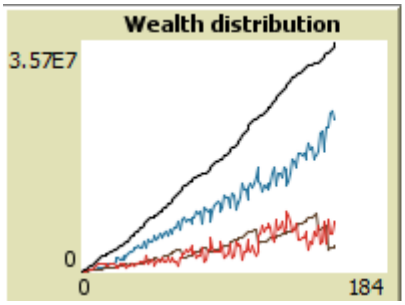
The reason is each time thief sees a police, he will turn back and run away. Each thief will move on the opposite direction as police so they are very likely to get together. When they become worker, they will work there, so a flock is formed. Moreover, the flock is formed in area with highest salary. The reason if a thief becomes worker and work in a place with low salary, the worker will become police or thief and move away. So flock can never be formed in area with low salary.

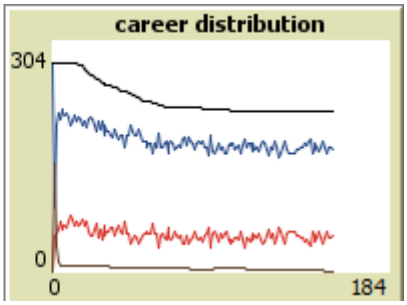
Now look at the wealth and career distribution. Here is turn off thief escape mode:





Here is turn on thief escape mode:





Here are the interesting results after turning on thief escape mode:

- The collective wealth of police decreases
  This is simple to explain because police can punish less thieves so as get less money from them.
- The population increases
  This is because less thieves get punished, which implies less people are close to die. So the overall population will increase.
- The total collective wealth increases
  This is surprising if also note the wealth of thief remains the same while the wealth of worker increase a lot. But it makes sense. Since more thieves will survive, and those have chance to become either worker or police in the future. If they become worker they will actually produce wealth.

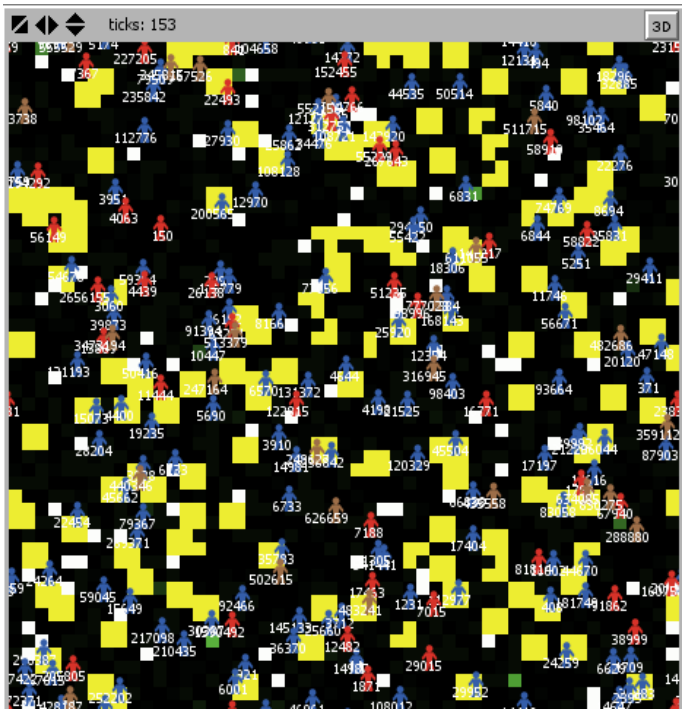
5.3 Catastrophe mode

The model also provide catastrophe mode which user can turn on or turn off. The idea is, catastrophe has chance to happen, and the job is gone at the place where it happens. Also, user can set rebuild chance which allows the society has chance to provide some new jobs.

The rules are: if catastrophe happens, randomly choose a circle by randomly choosing a position as center, and randomly choose a radius less than 2, set the color of the patches in this circle to yellow to represent catastrophe and set the job salary to zero, also set all turtles within this circle die; if rebuild happens, randomly choose a patch without job, create job there and set salary according to Boltzmann distribution.

The rationale is: the radius is randomly from 0 to 2 means the severity of catastrophe. To rebuild job, must choose one which is either is destroyed by catastrophe or has no job here initially.

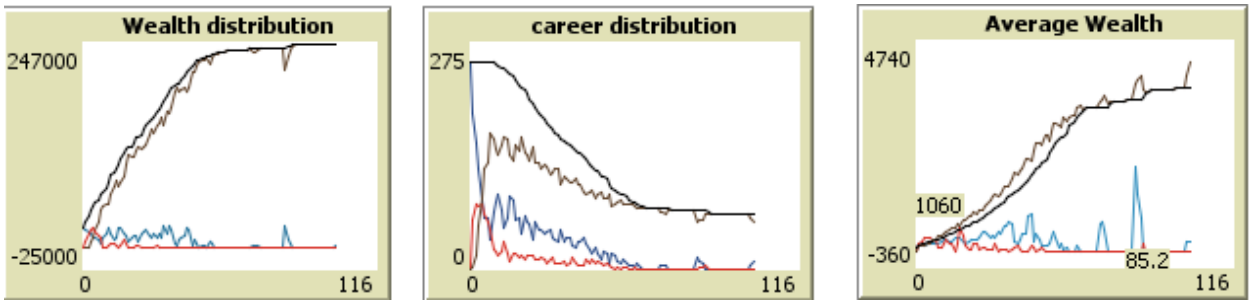
Here is example of running the model, remain same setting as 6.2 and set both catastrophe and rebuild probability to 100. The yellow patch visualize where catastrophe happens. Run the model to 150 ticks will see:



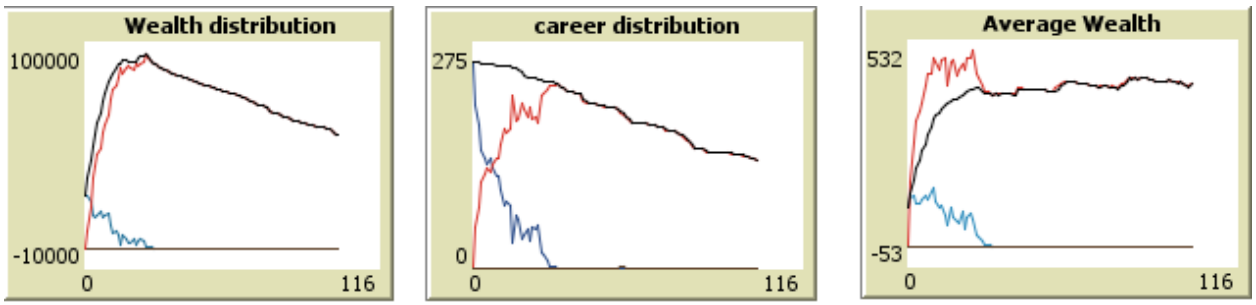
Intuitively this extension may not useful because if catastrophe happens constantly any society will die out finally. However, we can still observe what kind of society and polices leads to better performance when suffering catastrophe. Alternately we can observe what kind of influence catastrophe has.

5.4 Analyze of Catastrophe mode

This section is mainly analyzing how catastrophe makes different. Set the society as job-ratio 50, career -change-tendency 70, fair-factor 1.0 and living expense 2.



Case 1: Without catastrophe



Case 2: with catastrophe and catastrophe-probability is 100 while rebuild-probability is 0

From the three cases we can conclude:

Catastrophe destroys jobs constantly so people are harder to find job, this result in collective wealth becoming less. However, even catastrophe can kill people, the society with catastrophe ends with greater population at 150 ticks. This is opposite to our intuition but makes sense in this model. Consider this way: catastrophe destroy jobs, so tax rate is also not enough to pay for police, so thief conquers the world. They costs money constantly till they die. They only spend 1 money per tick. However in a society with police, police makes thief die quickly and thief also can make workers die quickly. This means an interesting result, in a world with just one career, no matter what it is, since they will not fight with each other, they can live longer.

6. Model extension: HubNet model

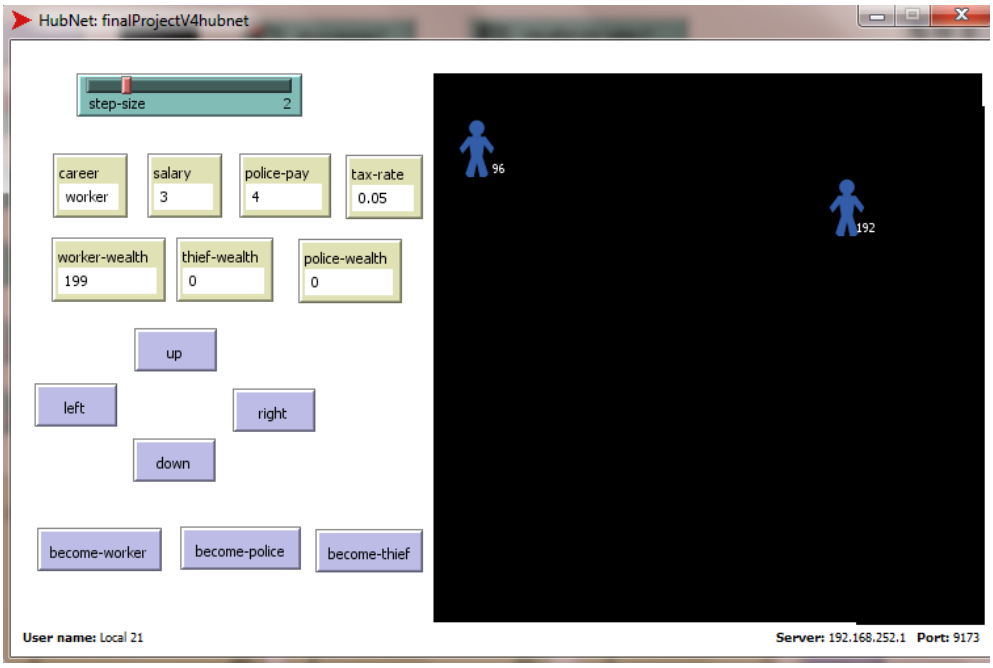
This section discuss the design and implementation of HubNet model.

When user join the game, he will initially be set as worker at a random position with 100 money. The idea is to offer the user some information so that they can take actions based on the information. The information include his career, the job salary, police pay, tax rate and the collective wealth of each career.

Note that when experimenting it is highly recommended to turn off visualize-job-salary? and show-money? switch. The reason is we want to only offer the user information that other system turtles know. Specifically, firstly because if player can visual the job salary all of them are very tend to go to the place with highest salary thus reduce the reliability of experiment result. The rationale is in real life people generally have no idea how to get the job with highest salary

initially, they need to explore the whole world to find out. Secondly if someone sees there is a huge rich people he will reach that guy and become thief run away. This will cause the game lost its sense.

User can move to another patch by clicking the directions buttons and also set different step size to move faster. User can also press buttons to change his career. The example of two players is shown as below:



To implement this, add a procedure which can listen player input in go procedure and let the turtles do corresponding actions. Also each tick update the information to each player.

7. Strength and weakness

This section discuss the strength and weakness of the model, it is helpful for readers and users to see what they can expect from model and for advanced users they can decide which part they can improve to make more precise result.

7.1 Mode strength analysis

This model takes into account multiple factors and provides lots of functionality. To summary, user can set a specific society based on seven factors: the initial population of worker, the initial population of police, the initial population of thief, job ratio, salary distribute fair factor, basic living expense and the tendency of people change career. And allows use set two police policies: tax rate and police pay. Moreover, the model provide thief escape mode and catastrophe mode. Different user may want to focus on different aspects. Therefore this model can be applied in multiple different cases.

Speaking of the core part, police policies, user can set up society according to the data of real world and to see which kind of policies lead to better society. Or user can also do some mental experiments by setting up an extreme society and observe how different kinds of polices work in extreme situation, it is helpful to consider the influence of a single policy.

7.2 Model weakness analysis

Nonetheless this model is not perfect for sure. Just like a trade off, by taking into too many factors, the model makes some assumption about the factors so the result may not be very precise as advanced user would expect. For example, the salary distribution ignores the tail in the figure which certain user may want to focus on. However, the model is programmed in a way that is easy to extend.

8. Future work

How police policy influent criminal activity and so career distribution and wealth distribution is a topic needs more research. Tax rate and police pay are complex issues, a dynamically change tax rate or police pay makes more sense in real life and may leads to more promising result. So a more thorough analyze using behavior space is needed. Also, there are other policies which can influence criminal polices, such as welfare. Lastly, fair-factor has some tipping point which remains mysterious and needs to be explored more.

Acknowledgement

Thanks for Professor Uri Wilensky, his interesting lecture makes learning modeling lots of fun. Thanks for TA Bryan who guides me modeling all the way and gives me lots of helpful suggestions.

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