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THE RELATIONSHIP BETWEEN ECONOMIC INEQUALITY AND CRIME THROUGH AN AGENT BASED MODEL APPROACH

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ABSTRACT:

The aim of this paper is to examine the relationship existing between inequality and crime.
Once the main definitions needed for the analysis have been set out, the link existing between inequality and crime has been deeply investigated through an empirical perspective and then through an agent based model approach.
Many previous papers have explored the relationship existing between the two phenomena through econometric techniques, and a positive correlation was found, but often econometric tools are limited in explaining social problems such as crime.
For this reason, in this paper we use an Agent-based modeling (ABM) approach, which is a type of simulation study, produced via a computer software, in this case Netlogo, that develops a virtual society and allows for controlled experimentation.
Once the simulation has been carried out, by looking at the results we can say that according to our model, inequality and crime rates are positively related.

KEYWORDS: Inequality, crime, agent based modeling, netlogo

General index

Images index

1. Introduction

We are now living in an extremely challenging era where most people are under pressure due to the increasing disparities caused by the rapid changes that we have been witnessing in recent times.

The matter of inequality affects us all considering that when the entire society and economy around an individual changes for the better he will have more chances to be successful and live a good life.

If we look at the statistics, we can say that there has been an historical push towards equality since the end of the eighteenth century, nonetheless, being pessimistic about inequality is quite simple, particularly in the delicate post pandemic era we are experiencing.

Especially for what might concern developing countries, such as Latin Americans ones, inequality rates have been drastically affecting the population, especially for themes regarding health and education but also crime rates and even if many overlook how high rates of inequality can be harmful to society, it is important to point out and explain the connections existing between such phenomenon and its consequences.

Criminologists have long considered that socioeconomic factors and inequality play a major influence in explaining why certain individuals become involved in criminal behavior and in impacting crime levels within specific societies.

The possibility of demonstrating a nexus between economic disparity and crime has preoccupied many social scientists and economists, who through empirical and econometric analysis have examined the matter at hand.

According to Becker (1968) income inequality represents one of the biggest "drivers" of crime while Fajnzylber (2002), among many others, has identified a positive relationship between inequality and crime, both within nations and across countries.

However, it is rapidly discovered in this sector that the correlations between income, wealth, crime, and victimization, although exhibiting some pretty evident patterns, are far from straightforward.

The complexity is linked to the very nature of crime itself since it is a social construct that is greatly influenced by the circumstances in which it occurs, and it also requires a challenging data collection which can be difficult using typical empirical methodologies.

Therefore, in this paper, differently from the past research on the affiliation between crime and economic disparity that have been conducted through econometric models or through empirical analysis, the study has been performed via an agent based model approach.

Agent based modeling is a method of computer simulation that generates a virtual society and allows for controlled experimentation.

This type of approach has the potential to be an effective tool for investigating criminology and may give fresh insight on criminological construct measurement in a variety of ways.
The attractiveness of ABM for social scientists stems from its ability to help in discovery, enhance comprehension, and simplify theory formalization.
The aim of this thesis is to identify and highlight through a computer simulation performed over an agent based model software called Netlogo, a relationship between inequality and crime.

2. Relationship Between Inequality And Crime

2.1 Economic Inequality

Defining a concept as broad,complicated and somewhat subjective as inequality is certainly no easy task but it results essential for our analysis to grasp its meaning and furthermore to understand how we can quantify this abstract notion to draw valid conclusions from our study.
There are indeed various forms of inequality but in order to not overcomplicate the analysis we will focus on the concept of economic inequality, meaning the disproportions in the distributions of incomes and other economic factors such as wealth, employment or human capital.
In other words, we might state that economic inequality refers to the contrast between the economic conditions of different individuals or different groups of individuals.
Hard work and good life choices indeed play an important role in influencing somebody's condition; but an individual's initial endowments, like its place of birth or its initial wealth, are crucial elements that will inevitably have even a deeper impact on the outcome of that person's life.
We could argue that some inequality is unavoidable and it is also needed because it encourages people to be more productive, to be inventive and to take risks; it allows them to be ambitious and work towards a better future; however the rate in which inequality is growing is indeed alarming.
On the other hand, In his notorious book "A Brief History of Equality" Thomas Piketty explains his theory on the roots of inequality and his blueprint for combating it, having a quite optimistic view on this matter and explaining that humans have been slowly gravitating towards a more fair and equal society.
It is indeed true that Inequality is increasing for more than 70% of the world's population, intensifying the risks of division and impeding economic and social growth, but according to

Piketty we should not feel powerless or worried about this current situation, we should rather Learn from our history and recommit to what works, including institutional, legal, social, economic, and educational institutions that have fostered equality.

Another significant element which is worth emphasizing is that, although is taking a really long time, we have been witnessing a slow deconcentration of property and power; considering the fact that the notion of property depends on the historical context and the correlated legal procedures and practices that structure and frame property relations and balances of power between social groups, we can see that there has been a significant rebalancing of the law in favor of the non-proprietary, which has helped to increased social equality and prosperity.

At the same time, we shouldn't forget that the concentration of property is still far from equal and to this day it continues to be extremely high, it is then safe to say that we should carefully not overestimate the magnitude of the evolution towards equality.

The fundamental issue is that excessive inequality may lead to social instability and class strife, considering that people often evaluate their economic well-being relative to others, not in absolute terms.

We can say that Individuals' perspectives on the fairness of inequality composition influence how they respond to inequality, in fact many people question the fairness of existing income and wealth allocations and advocate for a more equitable society.

It is no surprise that COVID-19 has been one of the many determinants that caused inequality to skyrocket in the past two years, especially in parts of the world where it was already high enough, such as the developing countries; but many more factors contribute to the daily increase of inequality and this is no good for us individual and for the society since it is often associated to heavy consequences that erode social cohesion and it is linked to undesirable societal outcomes, like political conflicts, higher infant mortality and most notably crime.

2.2 Brief Historical Background Of Inequality

When it comes to inequality, it's impossible to overlook the reality that Europe and the United States have had a distinct advantage over the rest of the globe for over four centuries.

Although there is widespread anxiety that China may overtake the United States as the world's leading power, the West's economic and social hegemony remains unquestionable.

It is somewhat paradoxical that, although accounting for only around 8% of the world's territory, Europe has managed to acquire a vital position of worldwide domination.

To help comprehend this phenomena, Piketty says that fundamental causes such as slavery and colonialism must not be disregarded since they are "intimately related" and may also help us better grasp global inequality dynamics.

Europeans conquered or occupied more than 80% of the world between 1492 and 1914. In many former colonial countries, decades of domination have resulted in persistent inequality and long-term effects such as poverty and low economic advancement.

Europe had a period of rapid economic expansion throughout the 16th century. As a result of major geographical discoveries, this growth had a tremendous influence on many other revolutions, notably the integration of Europe into a global economic system.

Of course, one of the major factors contributing to Europe's undeniable achievements has been industrialization: we must not forget that the continent hosted the industrial revolution, a remarkable economic transformation that facilitated Europe to obtain the technology, mentality, and attitudes necessary to put the ideology of global dominance into practice.

Slavery, which is considered the most severe form of inequality, was exceedingly common as a result of new discoveries and industrialization, and was only abolished by England in the colonies in 1833-1843.

Slave labor was necessary for the colony's early growth, which necessitated more people for work and other activities, which is why slavery was common. Slave labor also provided the major consumer commodities that served as the cornerstone of global trade throughout the eighteenth and early nineteenth centuries, most notably cotton, which was frequently exchanged by the English with India to get its valuable imports such as silk, spices, and tea.

Slavery was also significantly essential in French colonies; the example of Haiti, for example, is one that ought to be emphasized because the Haitian people are still suffering the effects of France's atrocities.

Slavery was introduced to the island by France in the 17th century, but the enslaved people fought back and gained freedom in the late 18th century.

The French never gave up hope of reclaiming their old territory, and they continued to threaten war.

To avoid this from happening, the Haitians' fromer enslavers obliged them to pay a large monetary settlement for their liberation.

The Haitians experienced the brunt of the consequences of France's theft, which was directly responsible for the country's underfunding of education in the twentieth century and its lack of health care as well as inability to build public infrastructure.

What happened in Haiti is just one of many injustices that occurred not long ago but continue to have an impact on our society to this day, not only morally but economically: France is directly responsible for Haiti's lack of economic prosperity, and it effectively guaranteed that

the Haitian people would continue to suffer the economic consequences of slavery for future generations.
Forced labor, like slavery, had a significant impact on the economic and social development of certain countries, such as Santo Domingo, Algeria, and Congo.
The situation of South Africa is also noteworthy: we must not overlook how devastating Apartheid was for society in terms of affecting inequality still to this day.
South Africa had a racial segregation policy and a political and economical discrimination against non-European communities, which only came to an end in 1994.
The introduction of the "Group Areas Act of 1950" under apartheid was a policy intended to foster racial inequality. As a result, millions of individuals were forced to leave their homes and relocated to designated places depending on their race.
The black population, who made up 80 percent of the population, was compelled to reside in reserves that accounted for little more than 7% of South Africa's total geographical area.
The previously detailed historical context is critical in understanding how colonialism, slavery, and military power allowed Western countries to rearrange the world's economy in their favor and permanently consign the rest of the world to a background position.
It is obvious that the inequality that exists in the world today is the result of a series of events that occurred in the past, and one way to combat it would be to acknowledge that these tragic historical events do indeed shape many countries' poverty and political unrests, and the only way to settle it (both morally and economically) would be for their former oppressors to first recognize it and then economically compensate them.

2.3 Measuring Inequality

Once we have defined what economic inequality is, it is useful for our analysis to examine the methods through which we can measure and represent this phenomenon.
Clarifying how we can measure inequality allows us to make comparisons and to better illustrate inequality between and within groups.
A useful tool for representing and comparing distributions of income or wealth, and showing the extent of inequality, is the so-called Lorenz curve, a graphic representation that shows the cumulative share of income from different sections of the population and it's convenient because it indicates how much disparity there is in income, or any other measure, across the population.
The horizontal axis of the graph displays the entire population lined up from the poorest to the richest while the height of the curve at any point on the horizontal axes indicates the portion of total income received by the fraction of the population given by that point on the axis.

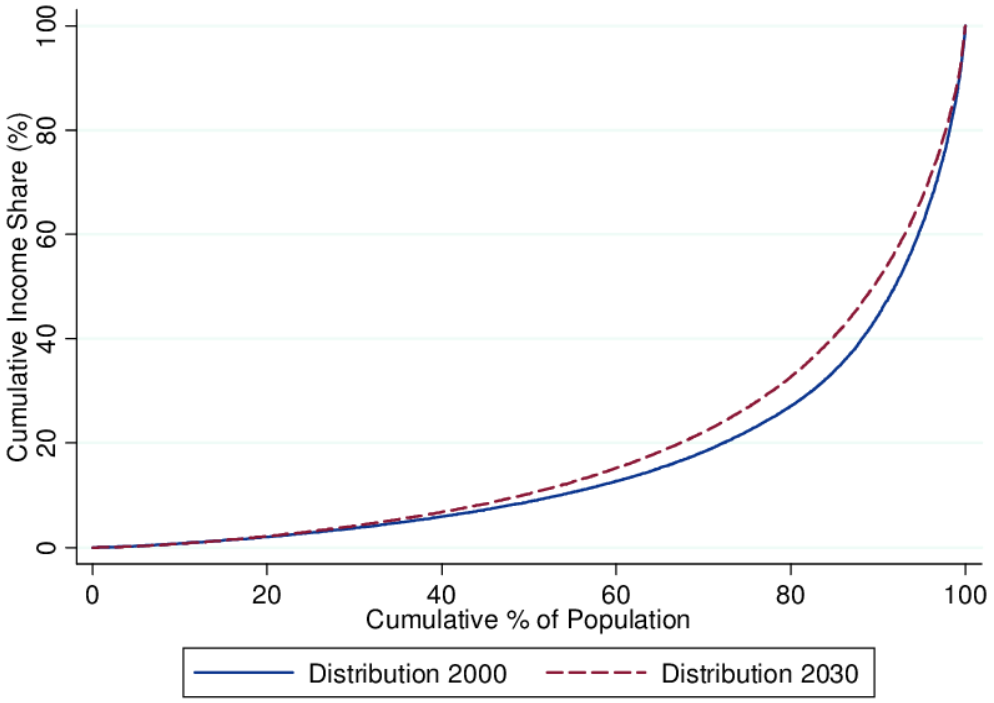
The Lorenz curve allows us to clearly see how far a distribution departs from this line of perfect equality being that more unequal distributions have a greater area between the Lorenz curve and the 45-degree line.

The following image, taken from a study conducted by Bussolo M., De Hoyos R. and Medvedev shows a representation of the global Lorenz curve of the year 2000, which has then been compared to the predicted Lorenz curve of 2030.

As we can see the horizontal axis portrays the cumulative percentage of the population while the vertical axis shows the cumulative percentage of income share.

Figure 1

Global Lorenz curve



Another characteristic of the line of perfect inequality is that it can be used to calculate the Gini coefficient- another critical indicator of inequality.

The Gini coefficient, named after the Italian statistician Corrado Gini, measures income distribution across a population and it is calculated as the ratio of the area between the Lorenz curve and the 45 degree line to the area of the whole of the triangle under the 45-degree line.

If everyone earns the same amount of capital and there is no income disparity, the Gini coefficient is equal to zero. When an individual earns all of the income, the Gini coefficient reaches its maximum value of 1.
The Gini coefficient is a valuable way to investigate income or wealth distribution within a country or area, but it should not be confused with an absolute measure of income or wealth, in fact, countries like the United States or Turkey that can be considered as economically successful indeed present an high Gini coefficient.

2.4 Economic Theory Of Crime

It is within human nature to cooperate to mutual advantage, however exploiting one another it is also part of the same unchanging aspects of individuals and in the most extreme cases these intrinsics aspects of humans result in criminal activity.
Many specialists have utilized the economic method to address a variety of issues, including criminal behavior, throughout the years: Becker, Ehrlich, Block and Heineke are within the most famous economist that have studied the economic theory of crime and that have elaborated famous and interesting economic theories that deserve to be explored.

- ***Theory of allocation of time of Gary Becker***

Gary Becker introduced economic theories and methodologies to subjects previously handled solely in sociology, demography, and criminology. He draws inspiration for this formulation from an event that personally happened to him that came to his attention (Becker, Nobel Lecture: The Economic Way of Looking at Behavior, 1993).

"I began to think about crime in the 1960s after driving to Columbia University for an oral examination of a student in economic theory. I was late and had to decide quickly whether to put the car in a parking lot, or risk getting a ticket for parking illegally on the street. I calculated the likelihood of getting a ticket, the size of the penalty, and the cost of putting the car in a lot. I decided to take the risk and park on the street (I did not get a ticket)" (p. 389).

According to Becker's utilitarian approach economic reasons are often at the origin of the behavior of criminals whose aim is to make a profit; he in fact adapts the rational consumer choice paradigm to criminal conduct in conditions of uncertainty. Criminal behavior, excluding the one motivated by personality disorders or irrational emotional impulses, obeys the rule of rationality: a rational individual makes the decision of committing a crime when the utility that comes with it is greater than the costs, which in this case are represented by how heavy is the punishment connected to the crime they decide to commit. Microeconomic theory can therefore help to explain some criminal behavior and prevent some of it by

creating policies that could potentially reduce the benefits that come with committing the crime and increase the risks connected to it.

- ***The theoretical model of Isaac Ehrlich***

Another study that became essential in the economic evaluation of crime is dated 1973 and is carried out by Ehrlich.

It is a model of choice between legal and illegal activity formulated following the economic theory of choice in conditions of uncertainty. The central hypothesis is that, in a given period of time, the individual can find the right amount of time to devote to each of the two activities to achieve maximum utility. The yields of the two activities are not fixed exogenously as in Becker's scheme but are an increasing function of the time devoted to each of them. Differently from before, when the individual could only choose one alternative (whether to commit the crime or not), he considers a more sophisticated version of the decision process that permits a more subtle variation among the alternatives. Individuals in this model have now the opportunity of choosing the combination of activities that assures them the highest possible level of utility. When an individual decides to commit a criminal offense, he does it because it can produce an increase in his levels of physical and psychological satisfaction or because it can generate economic gains. On the other hand, an individual has to take in consideration that when he commits a crime there are several hazards that might lead him in a worse condition compared to his initial situation. His utility can in fact diminish or he might have to serve or pay a penalty, additionally he witnesses an increase in the probability of being unable to obtain work due to having a criminal record. It is also important to consider that pursuing a lawful and legitimate career also implies risks of various kinds, so the two alternatives (commiting a crime or not committing a crime) share the common ground of being characterized by incertancy. In this model it is therefore assumed that an individual can carry out two types of activities: legal and illegal and we can assume there are no costs implied of any kind. The legal ones are safe options even if they are characterized with incertancy, while the illegal ones are risky because there are chances of capture and punishment, plus a return is not guaranteed. If the criminal is successful, his net gain will be represented by the difference between the revenues and costs he has incurred. If, on the contrary, he is caught red-handed, the costs of punishment and other losses will be deducted from his profit (Ehrlich, 1973). In conclusion, the individual determines for himself how to optimize his own usefulness by allocating his available time, deducing the free time that is deemed fixed in this situation (Ehrlich, 1973). This indicates that the gain from the two activities is proportionate to the amount of time devoted to him.

- ***The theoretical model of M. K. Block e J. M. Heineke***

Heineke and Block (1975) develop a work which is similar to Ehrlich's for many features, especially with regard to the formalization of the problem. It focuses on the choice of the optimal level of time to be devoted to lawful and illicit activities to derive maximum utility, following a much more subjective perspective. Their model is also based on the principle of expected utility, but they decided taking into account only crimes against heritage. They also consider an individual who must optimally allocate his time between two types of activities: legal (work) and illegal (theft). The gain of the individual therefore depends on how he chooses to spend his time, although his wealth is made up of two other components, in addition to the first one: the gain from professional activity and the gain from criminal behavior. To the latter, however, the monetary amount for each infraction multiplied by the arrest and capture rate must first be subtracted. According to Block and Heineke it is thanks to the probability of success and to the tendency of risk that the individual gains utility from committing illicit activity. Furthermore, Block and Heineke's model also takes into consideration really subjective components of humans, such as the role of ethics and morals in the individual's decision to commit criminal acts. As a result, crimes are more likely to be committed when the reward is greater than the predicted expenses and psychological disadvantage of engaging in illegal activities. It is also logical to think that when the consequences that follow an illicit act are more serious, legal activities have advantages over illegal ones. However, risk appetite, which is entirely subjective and unique to each individual, may discourage or, on the contrary, stimulate participation in criminal activity.

2.5 Types Of Crime

It is now appropriate for our analysis to throw light on the notion of crime, given that it is an extensive concept and many types of crime exist, furthermore it is logical to think that the effects on inequality change depending on what type of crime we are considering.
Criminologists frequently classify crimes into many broad groups: (1) violent crime; (2) property crime; (3) white-collar crime; (4) organized crime; and (5) consensual or victimless crime.

- ***White collar crime***

The term “white collar crime” was coined in 1939 by Edwin Sutherland during a presentation to the American Sociological Association and it refers to that range of frauds committed by businessmen and government professionals.

This specific term is a social construct which is hard to define and identify, since it is often seen as a victimless type of crime.

Edwin Sutherland defined the concept of white collar crime as *“crime committed by a person of respectability and high social status in the course of his occupation”.*

Recognizing that white collar crime exists makes us understand that criminal acts are committed by individuals from all social and economic classes.

Three elements are commonly used to differentiate white-collar crime from other types of crime:

1) White-collar crimes are those committed while being on the job.

2) the offender’s occupational role plays a central feature in the perpetration of the crime.

3)Society views the offender's employment as a legitimate occupation.

White collar crime could happen at any level within a company and the higher the position of the criminal, the higher is the damage that can be done.

There are three categories of white-collar crime. The first is organized fraud, which includes embezzlement, extortion, forgeries, and fraud. The second type is represented by offenses against public administration including bribery, obstruction of justice, official misconduct, and perjury. The third one is administrative, environmental, labor, manufacturing, and unfair trade practices are examples of regulatory infractions.

- ***Violent crime***

Violent crimes are classified into four categories: Murder and non-negligent manslaughter, Forcible rape, Robbery and Aggravated assault.

Because it includes the taking of a human life, homicide is considered the most severe crime. Additionally, homicide data are thought to be more reliable than other crime data since most killings are reported to police and are more likely to result in an arrest than other crimes.

Robbery involves theft by means of force so even though it might seem that it could be classified as a property crime, it is actually a violent crime.

As we might imagine, these datas all suffer from under-reporting bias.

- ***Property crime***

Property crime includes crimes that are not directed specifically at individual people. Rather, these crimes are aimed at property. With property crime, property may be destroyed or defaced in some way. Usually people aren't injured since the intent is typically focused on obtaining or defacing the property in question, but it's possible that individuals may be harmed, as in the case of arson. There are numerous types of property crime, Burglary Theft

larceny are some of the most common ones. As for violent crimes, property crime dataset also suffer from under-reporting bias.

- ***Organized crime***

Organized crime is a network of highly centralized companies that exist solely to engage in illicit activity.

Cargo theft, fraud, robbery, kidnapping for ransom, and the demand for "protection" fees are all crimes committed by such groups. The supply of illegal but ongoing public demand products and services, such as narcotics, prostitution, loan-sharking (i.e., usury), and gambling, is the primary source of revenue for these criminal syndicates.

- ***Consensual crime or victimless crime***

Consensual crimes are those in which the victim is the state, the court system, or society at large, and which impact the system's broad (often ideological or cultural) interests, such as common sexual morality. Victimless crimes, while similar in nature, often entail single-person activities. Drug use is typically regarded as a victimless crime, whereas the sale of drugs between two or more individuals is regarded as a consensual crime. Because no one has come forward to claim injury, the two terms are essentially interchangeable in common usage.

2.6 Property Crime

Because a comprehensive examination of the many sorts of crime would require several chapters, in this paper we are going to deeply delineate only the concept of property crime which is the one we will need for our analysis and simulation.

Property crime has been interpreted in several ways. The FBI's Uniform Crime Reports classify property crime as the theft of assets without the use of physical force or threats.

However, in reality, property crime can often involve violence. Although not universal, the widest and most basic definition of property crime is as follows: criminal behavior involving the exchange or destruction of property, including money, automobiles, jewelry, shoes, narcotics, or other kinds of wealth, whether or not violence is used or threatened.

Robbery, abduction, carjacking, tax evasion, fraud, burglary, auto theft, shoplifting, vandalism, arson, fencing, and illegal drug trafficking are all manifestations of property crime. The following is a list of the main kinds of property crimes:

- ***Violent Property Crime***

In this case, during the course of the encounter, the perpetrator uses or threatens to use force on a victim. This includes both crimes in which the violent act is the aim, such as murder or rape, and crimes in which violence is only a means to an end. Violent crimes may entail the use of weapons, however some violent crimes may not necessitate the use of

guns. Cases of violent crimes range from harassment to killing, depending on the jurisdiction. Carjacking and armed robbery are two common examples of violent property crime

- ***Fraudulent Property Crime***

The use of purposeful deceit to achieve illicit gains or deprive victims of their legal rights is referred to as fraudulent property crime. For example, fraud is a civil law infraction. As a result, victims of fraud can sue perpetrators to either avoid the scam or receive monetary compensation for their losses. All scammers are sentenced to jail. Tax evasion and embezzlement are two common instances.

- ***Stealthy Property Crime***

This is defined by the law as non-consensual, non-violent, and non-fraudulent property theft. For the crime to be termed stealthy, it must be accomplished while the victim is absent. Larceny or burglary is the most prevalent kind of these offenses.

- ***Destructive Property Crime***

The unlawful or criminal destruction of property is classified as this form of property crime. Vandalism and arson are two common examples. Destructive property crime frequently leads to further criminal charges. For example, someone who sets fire to another person's property may be charged with arson as well as attempted murder (violent property crime).

- ***Entrepreneurial Property Crime***

This arises when someone unlawfully produces, sells, buys, transports, or distributes a property. Counterfeiting, selling or transporting stolen goods, and dealing in illicit commodities and drugs are all examples. Entrepreneurial crimes, like its covert equivalents, can lead to further criminal accusations. For example, it is not unusual for violent offenses to coexist with drug accusations.

2.7 Inequality Increases Risk Taking Behavior

From a sociological point of view ,crime is a risk-taking behavior that present hard consequences on who commits it, the theory of "relative deprivation" suggests that a strong difference in income can increase feelings of deprivation and injustice, causing poor individuals to attempt to reduce "injustice" even if is through a risky crime.

From an empirical point of view, we can imagine that in societies with a high gini coefficient, individuals with low income are more motivated to commit a crime than in equal societies, but the reasons behind this are certainly not trivial.

From an economical point of view we can say that people allocate time between criminal activity and market by comparing the possible future returns, In countries with a high Gini coefficient, low-income individuals and high-income individuals coexist in the same society

and depending on how likely and severe is the punishment that would follow a criminal act, they choose whether to commit it or not.
Research in the past has shown that usually the returns expected by committing a crime are higher for low-income individuals, even if the risks related to criminal behaviors are higher.
This is because human perceptions of need can be impacted not only by financial resources, but also by subjective variables and relative comparisons, and hence by inequity.
Well-being is in fact a subjective assessment of one's happiness, contentment, and satisfaction with one's life; and research shows that people compare themselves to others in order to measure their own position on critical aspects, particularly when objective standards are unavailable.
Financial resources are a key component on which people make comparisons given that is one of the main factors that influence an individual's satisfaction, however evidence shows that the concept of absolute wealth is not what drives the association between satisfaction and income, relative income is.
Money gives an objective meter for earning, but there is no objective criteria for determining how much one requires to be fulfilled. Studies have shown that Individuals are less content with their income if their neighbors are wealthy, even if their own income is steady, this concept gives a reasonable motivation on why crime rates are higher in countries where inequality is higher.
In general, upward comparison to individuals with greater wealth drives people to believe they require more to be satisfied, therefore people are prepared to take more risks in order to fulfill such needs. We can conclude that the presence of inequality certainly influences risk taking mechanisms and individual decision making.

2.8 Criminality And Inequality

In this case, as we have already mentioned, the literature focuses on analyzing the possibility that greater inequality may generate higher crime rates.
As we analyzed before, since Becker (1968), individuals in the economic theory of crime have allocated time between market and illegal activities by evaluating the predicted performance of alternative options and taking into consideration the expected consequences.
According to these theories, inequality increases the motivation to commit crime because low-income people live near high-income people who own commodities (or have access to services) that they can’t have access to if they pursue a lawful type of career.
Hence, people that suffer the consequences of inequality have the incentive to look for illegal ways to achieve that goal.

Ehrlich's work, which has been previously examined, shows a favorable report, which was substantially confirmed by future contributions.

For example, If we give a look to the paper produced by Chiu and Madden in 1998, we can find a formal modeling of the link between inequality and property crimes, and we see that through their work a positive relationship between the two phenomena have been found.

In fact, in their work, they provide a theoretical economic model that shows a probable relationship between growing income inequality and increases in the frequency of house robberies.

Starting from this suggestion, a considerable quantity of empirical works has been produced, in search of the confirmation or the denial of this theory.

Nivette, A.F (2011), by conducting a cross-national study to understand what factors might be the possible determinants of homicides, found that inequality is indeed a strong predictor of crime, and even if crime rates are constantly changing over time, such indicator can't be overlooked.

In 2015 Kang, S. discovered a link between violent crime and economic disparity, which is mostly driven by inter-neighborhood economic segregation rather than within-neighborhood inequality.

Another interesting analysis concerning the relationship between property crime and inequality, conducted by Goda T. and Alejandro T.G (2019) proved how the concept of absolute inequality, in contrast to relative inequality, is a reliable and statistically significant predictor of violent property crime rates.

Furthermore, by studying the paper of Heimer (2019) we understand how criminology is rooted in economic, racial, ethnic, gender, and other disparities, and that in order to understand the correlation between the two we have to recognize how important is the role of inequality in explaining crime patterns.

The possible causes and consequences of inequality have also been deeply investigated in Polacko M.'s recent work (2021), which by conducting an econometric study showed that among other severe consequences of such phenomena, crime was definitely one of the most impactful.

He showed that in more egalitarian countries, violent crime rates are lower; this can be attributed to the fact that less egalitarian societies place a greater social emphasis on economic achievement while providing fewer resources to do so, and thus the social tension generated by this situation may lead to an increase in the number of people turning to crime as a means of gaining financial success.

Although there are a significant amount of works that confirm the presence of a strong relationship between the two phenomena, what remains unclear is the causality of the relationship, that in many works results statistically significant in both directions.

In fact, the direction of causality also raises doubts from a theoretical point of view: we know now that it has been proven by the economic theory that inequality can increase the incentive to crime, but on the other hand it is also true that there are reasons to believe an inverse relationship, meaning that it is possible that crime generates inequality.
It is logical to think that the presence of criminality in certain areas gives a reason to the rich people to live in other parts where criminal activity doesn't occur that often, and this phenomenon definitely contributes to an increase in criminality because It promotes physical segregation between wealthy and poor, which can maintain or worsen economic and social status inequalities.
This circumstance also reflects on education given that poor students will live in crime-prone areas, have worse schools, worse education, and therefore worse job prospects.
Furthermore the presence of criminality in an area also affects incentives for participation in the school system since "successful" criminals could be seen by children and teenagers as role models, especially in the poorer areas, obstructing another common route of social mobility.
In 2004 Barrera and Ibáñez, with data on Colombia, showed how the presence of crime can significantly reduce the rate of participation in the education system and school results; the same conclusions have been drawn by Jarillo in 2016 with datas related to Mexico.

3. An Agent Based Model Approach

3.1 Agent Based Model: A Revolutionary Approach

Over the past years a new modeling approach called Agent based model approach (ABM) gained increasing attention since it represents an appropriate technique for a large category of problems and it has advantages over conventional modeling approaches in many cases.
Its uniqueness stems from the employment of a computer program explicitly expressing cognition and the interaction of "agents" (simulated social actors) to investigate the collective consequences of these.
We could define the agent based model approach as type of generative simulation modeling through which we can bring into existence a realistic artificial world comprised of autonomous interacting agents, which represent real world entities such as individuals, organizations and groups, and a landscape.
The most fundamental cause for ABM excitement is dissatisfaction with the constraints imposed by alternative modeling formalisms.

When studying an economical or social model, systems of differential equations, statistical models and econometric models are the most often utilized alternatives.

These dueling methods have made significant contributions to social science and economic science, but are considered as imposing restrictive or unrealistic assumptions that limit their use to a wide range of situations.

This is why computer simulation holds the potential of allowing us to investigate difficulties that have previously been ignored in theoretical sciences focused on mathematical reasoning.

The necessity to state problems in a tractable manner for mathematical analysis or proof frequently necessitates assumptions that can be eased using computer simulation.

When it comes to understanding economical and social science, computer simulations allow us to capture and explore Imperfect rationality, the consequences of learning and information, and institutional structure, to name a few.

However, these significant new applications of computational science are now hampered by a lack of clarity regarding the uses of computational models and the requirements for persuasive arguments based on them.

On the other hand, computational modeling is commonly acknowledged as beneficial for issues when models that accurately forecast the future behavior of systems of interest can be constructed.

Once it is realized that computational modeling is better understood as an example of experimental mathematics, concerns of credibility and suitable technique become considerably more manageable.

The Agent based model approach has the significant advantage of working through autonomous agents that provide a place to represent the tremendous quantity of data and knowledge about social agents' behavior, intentions, and interactions, contrary to other formalisms, such as differential equations or statistical models, that are primarily applicable to aggregated data.

Agent-based models provide a surprisingly strong formalism for utilizing precisely the type of information that many social sciences are interested in, since they are able to take into consideration what we might refer to as the “human component”.

Given that the agent based model approach is a relatively new approach, there is a scarce literature of models especially regarding crime and its relationship with inequality, but in the past couple of years, ABM has been used as the principal approach in a number of criminology articles such as Groff 2007, Birks 2012; Weisburd 2017 and Birks 2014; Johnson and Groff 2014; Pitcher and Johnson 2011.

Groff, E.R., Johnson, S.D. & Thornton, A. (2019) in their paper examine the reason why ABM has been considered to be a promising methodology for researching criminological

theory while Calderoni, F.Campedelli, G.M Szekely, A. have used an agent based model approach to see how four different policy scenarios affect recruitment into organized crime. We can then understand the potential of this type of approach when it comes to utilizing it for social science applications such as criminology.

3.2 Agents And Their Characteristics

Agents feature certain properties and attribute, just like if they were real individuals with their own characteristic in a population, allowing them to be a reliable approximation of actual human beings and therefore facilitating the formalization of theories. As in real life these characteristics can change over time allowing us to model heterogeneity in a dynamic way. ABM's capacity to dynamically represent heterogeneity is a major attribute since it can imitate the variance of real life. Agents have the property of living in an environment, and they interact with the environment as well as with the other agents, the simulated landscape might be basic or complicated, and it should represent the research topic that the modeler is attempting to answer.

Furthermore, agents are situated, in the sense that their behavior is situationally dependent, which means it is influenced by the present condition of its interactions with other agents. An agent can be considered as social, meaning it can interact with other agents. Because of their dynamic interactions, even agents with very basic behavior rules may yield extraordinarily complex and surprising results.

We can consider an agent to be autonomous and self-directed, meaning it can function independently in its environment and in its interactions with other agents, moreover an agent is identifiable, discrete and has decision making capability.

The decisions made by one agent, can influence those of others directly as a result of their presence or their actions, or indirectly.

Moreover, An agent's behavior may be guided by specified goals. The goals are not so much objectives to maximize as they are criteria against which to evaluate the success of its decisions and activities. This enables an agent to compare the outcomes of its actions to its goals on a continual basis, providing a standard for potentially changing its behavior.

Based on its experiences, an agent may be able to learn and adapt its behavior.

Individual learning and adaptation necessitate the presence of memory in an agent, which is often in the form of a dynamic agent characteristic.

Lastly, Agents contain numerous resource qualities indicating their current supply of one or more resources, such as energy, wealth, information, and so on.

3.3 Applying The Agent Based Model Approach To Criminality

Once we have defined the main features of the agent based model approach and understood the useful characteristics through which agents work in the simulation, we can now express why this approach is ideal while working with social issues such as crime and inequality.

In order for criminologists to explain crime and criminal behavior an analysis of individual decision-making within the context of long-term social dynamics is necessary.

Groff, E.R., Johnson, S.D. & Thornton, A. (2019) explain in their paper that given the multidimensional nature of social processes, which encompass geographical, temporal, and cultural elements, typical empirical techniques to data collection, such as statistical techniques, and modeling present a variety of obstacles.

Problems in empirical measurement can have a negative impact on the strength of a theory, given that inadequate measurement results in the inability to prove or refute hypothesis.

Epstein and Axtell (2006), Epstein (2008), Epstein and Axtell (1996), have introduced a generative method, which investigates how macroscopic regularities, such as crime patterns in space and time, emerge from discrete acts and interactions.

In order to develop this sort of approach, It is necessary to have a computer laboratory in which the researcher may develop an artificial community.

Individuals in the artificial society, known as agents, act in accordance with the principles of criminological theory. The model's agents interact, and the researcher examines if the consequences in the artificial society correspond to what the theory would predict.

The ABM(Agent based model approach) that we have explained in previous paragraphs is one type of generative approach.

The main reason why Agent based model approach is revolutionary when it comes to studying crime dynamics, is that it is very well known that crime reports datas are often biased and suffer from substantial shortcomings.

Aside from measurement concerns, empirical approaches have significant limits when it comes to verifying theory: the measurement of both dependent and independent variables of importance to criminologists is difficult, costly, and sometimes unethical or imprecise since they involve latent constructs assessed indirectly through observation.

ABM on the other hand, facilitates causal analysis while also allowing for the exploration of processes at the same time, by generating a counterfactual with no random assignment.

The baseline model is the counterfactual model because it depicts society without any intervention.

ABM may be used by modelers to evaluate various assumptions by creating a set of experiments, such as what-if scenarios which progressively modify one feature of the model while maintaining the others constant.
Therefore, if we assume that the model is stochastic, numerous runs of each condition will lead to alterations in results, allowing the impacts of chance and uncertainty to be evaluated.
We can say that the ABM approach is definitely revolutionary when it comes to studying criminality, and it should not replace traditional empirical procedures, but rather it could play an important role in a research program that employs a range of different methods.

3.4 Agent Based Modeling Softwares: Netlogo

The software used to construct an agent based model has a significant impact on the development time and there are various useful toolkits that can be used to build agent based simulations.
The following are some of the most commonly employed softwares used to carry out simulations of this kind:

- Swarm
- Repast
- Ascape
- Mason
- Mass
- Breve
- Netlogo

In this paper, the simulation will be carried out with the software Netlogo, which is a programmable multi-agent modeling environment created by Uri Wilensky in 1999 at Northwestern University.
NetLogo is an open source, cross-platform modeling tool that allows users to simulate a wide range of natural and social phenomena (including biology, chemistry, computer science, economics, physics, psychology, art, and much more).
It was created in the style of the programming language Logo, with the goal of being "low threshold and no ceiling." It teaches programming fundamentals by utilizing agents such as turtles, patches, links, and the observer.
NetLogo was created with several audiences in mind, including teaching youngsters in the education community and domain specialists without a programming experience to simulate relevant phenomena.
Furthermore, NetLogo has been used in the publication of several scientific papers.

This software is the most widely used ABM environment, probably since it is the easiest to learn.
Netlogo has essential design principles that facilitate the use of this software, as mentioned before it has been created with the goal of having a low threshold to understanding and comprehension of the models or for creation of the models, making it so that even novels can build simple models at first use.
The software is also equipped with a pre-collegiate curriculum that includes complex systems and modeling and it has also been used in university courses to include model-based inquiry.
On the other hand it also has a very high ceiling, in the sense that the language is expressive enough to enable high and complex models, making it possible for researchers to read, write and publish models.
Thanks to this important feature of netlogo the gap between the modeler and the programmer has been eliminated, enabling interactive development and research and making it also easy to share.
Finally, Netlogo also contains a set of simple tools for creating graphical representations of the simulation's state, allowing for extensive inspection of the simulation throughout creation and application.

3.5 Operating In Netlogo

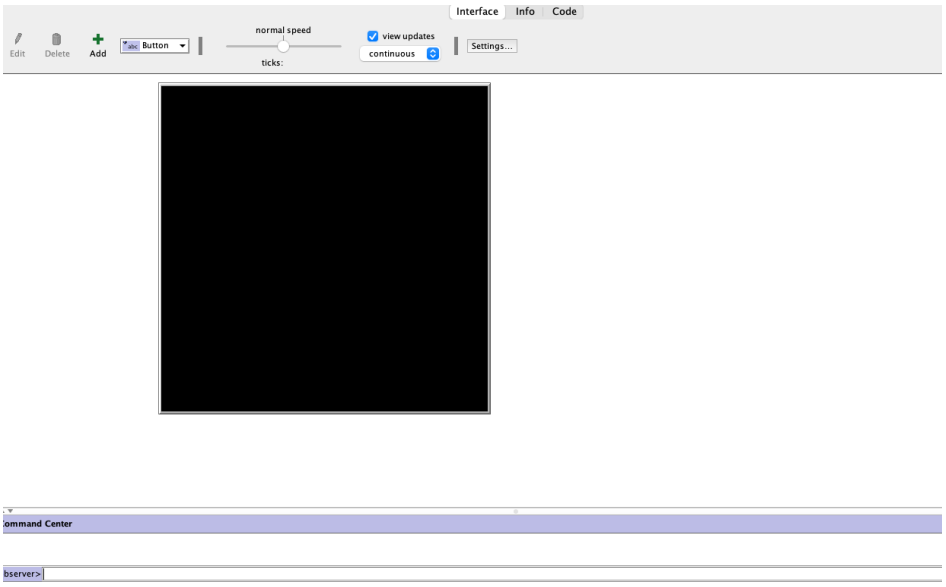
In Netlogo, the agents are set up by assigning them qualities, much like in the foundations of agent-based modeling. The software permits you to create an environment in which the agents interact, according to the rules that can be created and that govern how the model works. The simulation is then conducted and observed.
The interface provides a two-dimensional spatial perspective of the model world; the items you build can all be moved around the interface by clicking and dragging them one by one or numerous at a time. A right-click also provides you the opportunity to customize the element, allowing you to create the right interface that makes the model more comprehensible for those who interact with it.
The size of the real grid, which is the black area where the simulation occurs, can also be altered.
Netlogo is composed of three tabs:

- ***Interface***: the first tab is where the simulation takes place and where you can observe the agents that have been created and their environment. In this tab, every agent and function that has been programmed together with the buttons will be

shown. The grid is made up of cells, and all events inside it are placed and move around an x and y axis.

Figure 2

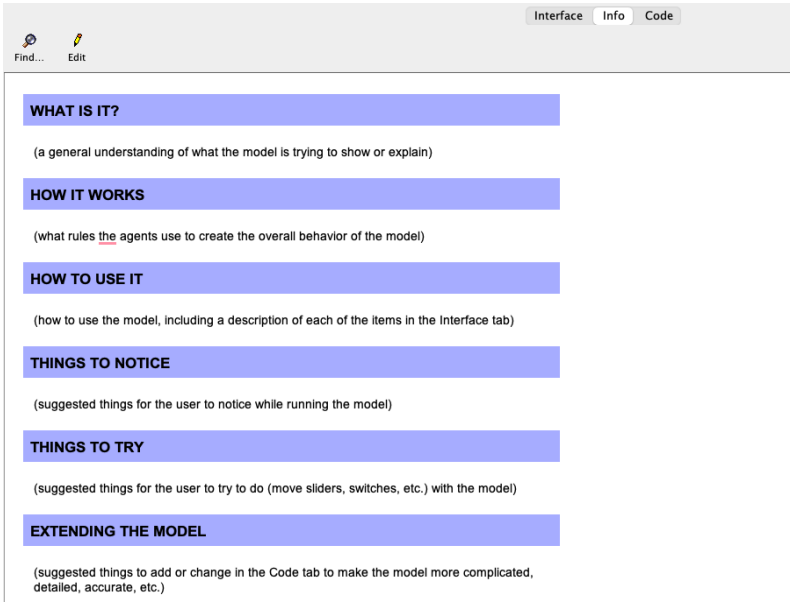
Interface of Netlogo



- ***Info***: The second tab, contains information on the code that was developed for the model. The observer can investigate the model's fundamentals and determine which little or major changes can be made to the model to alter the simulation's outcome.

Figure 3

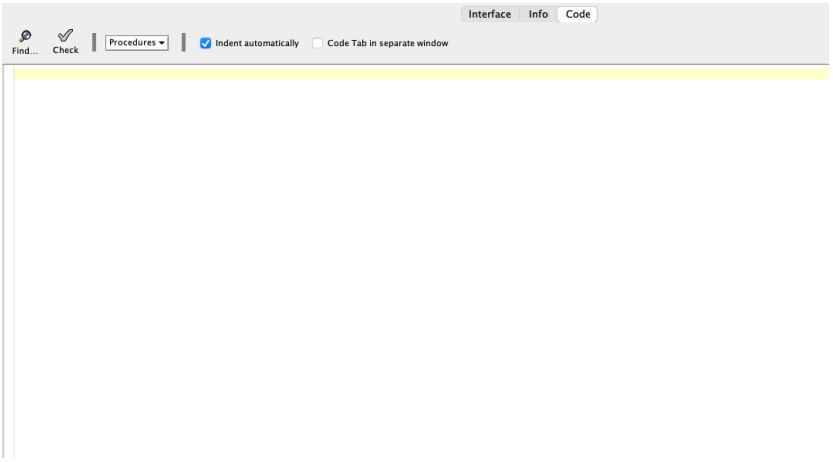
Info tab of Netlogo



- ***Code***: The code tab is where the model's back-end code is completed, this is a fundamental tab since all the characteristics that the agents and environment will feature will have to be coded in this tab.

Figure 4

Code section of Netlogo



The word is a grid that features basic regions known as patches, and it's where the simulation happens and is represented by the black window that you see in the interface. Each patch is a 2x2 grid cell that is identified by the coordinate in its center.

There are three categories of agents that can occupy the world: mobile agents, stationary agents, and connecting agents. Mobile agents, such as turtles, can move around the simulation. Stationary agents are patches that cannot move but can nonetheless participate in the simulation. Finally, connecting agents serve as bridges that connect two or more agents.

A turtle is a mobile entity in the world, with a position and a direction at all times. Shape, size, and color are some of the other characteristics you may give them. When gathering data, factors like age or gender can be added to the turtles, although they do not always have to affect the turtles' function or how they interact with others.

When starting to work in a simulation, it's important to create two buttons that will allow you to get the world running, these are the setup button and the run button.

By clicking on the "setup" button you set up the world you have created, while when you click on the "run" button you make the simulation function.

4. Simulation

4.1 Schelling's Segregation Model

In Netlogo there is a vast "models library" where users may see the many sorts of models which feature good coding and documentation practice and that have been previously created with the toolkit. These are often well documented, and the documentation is easily available via the program's "information" page, furthermore they can also be used as a base to develop other models and be later modified, adding the optimal features to carry out a simulation that would properly depict the phenomenon we are considering.

Thomas Schelling, an American economist, developed one of the first instances of agent-based models in 1971 that showed how unintended conduct might potentially contribute to segregation.

His model is useful to understand how discriminatory preferences affect community structure.

One of the most basic versions of Schelling's segregation model is a stylized portrayal of a residential area in which individuals continually make relocation decisions based on the features of their immediate surroundings.

The model takes into account different classes of agents, Orange and Blue, which could represent various races, ethnicities, economic status, and so on, as well as a NxN grid of residential sites across which a number of agents are first randomly assigned.

Each neighbor has eight neighbors and the basic model assumes that agents are only concerned with their immediate surroundings.

Agents have the ability to discriminate, which is considered to suggest that they can differentiate between their own group and other groups.

Discrimination, on the other hand, does not mean that the agents dislike (or favor) the other group, nevertheless, the agents' preferences may be motivated by "discrimination."

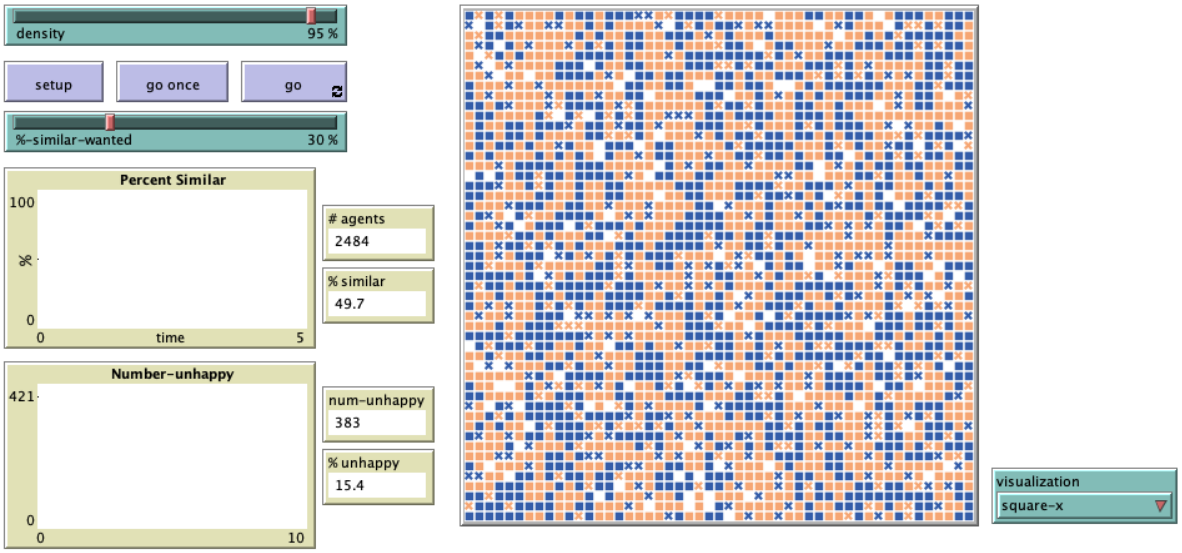
Orange agents, for example, may choose to reside in the same neighborhood as Blue agents, while blue agents may prefer to dwell solely in areas where there are no orange agents.

Agents in the Schelling segregation model feature a property called “happiness”, which depends on their discriminatory preferences and therefore on the kind of neighbors they have to live close to.

The image below shows the interface of netlogo once the “setup” button has being clicked, and therefore when the agents have been randomly placed in the grid:

Figure 5

Interface of Netlogo once Schelling's segregation model has been setup



We can see in our simulated world both happy agents (represented by a normal square) and unhappy agents, which are easily recognizable because they are indicated with an “X”.

We also notice how the density of the population is set to 95%.

As we mentioned before, the happiness of an agent depends on the discriminatory preferences: we can differentiate mild discriminatory preferences and strong discriminatory preferences.

A significant discriminating preference indicates that the agent prefers to reside in a community where people of its own type predominate, while a mild discriminatory preference indicates that the agent is content to live in a minority neighborhood and can endure minority status up to a degree.

This model was developed with the intent of analyzing the interaction of agents who have mild discriminatory preferences.

In this model, the discriminatory preference is indicated by the “percentage of similar wanted”, which is set to 30% as we can see in the image below:

Figure 6

Discriminatory preference of the turtles

To better explain this concept, we can say that the orange and blue agents get along well together, however, in order for the agents to be “happy”, they must reside near at least 30 percent of "their own ", which is quite low considering that is less than 50%.

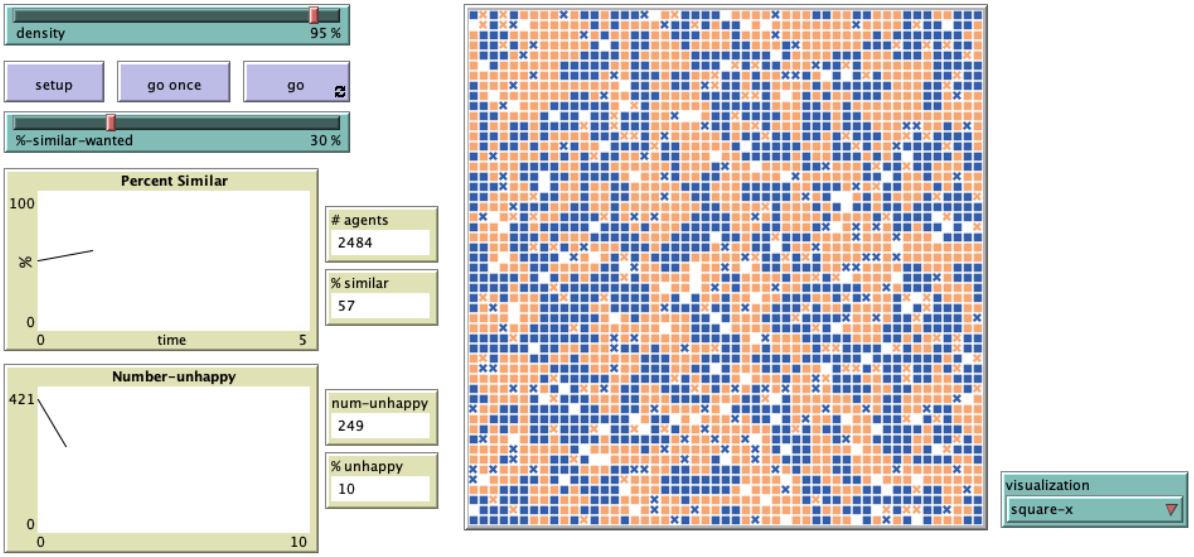
The agent will relocate into a different vacant residential location when unhappy and this dynamic will continue until a stable equilibrium (if one exists) is reached, in which all agents are pleased.

By pressing the button “go once” the simulation will run once and agents will resettle to another free spot in the map resulting in a decrease in the number of unhappy agents.

Nonetheless, we can see that various unhappy agents are still present on the grid, so a state of equilibrium is yet to be reached.

Figure 7

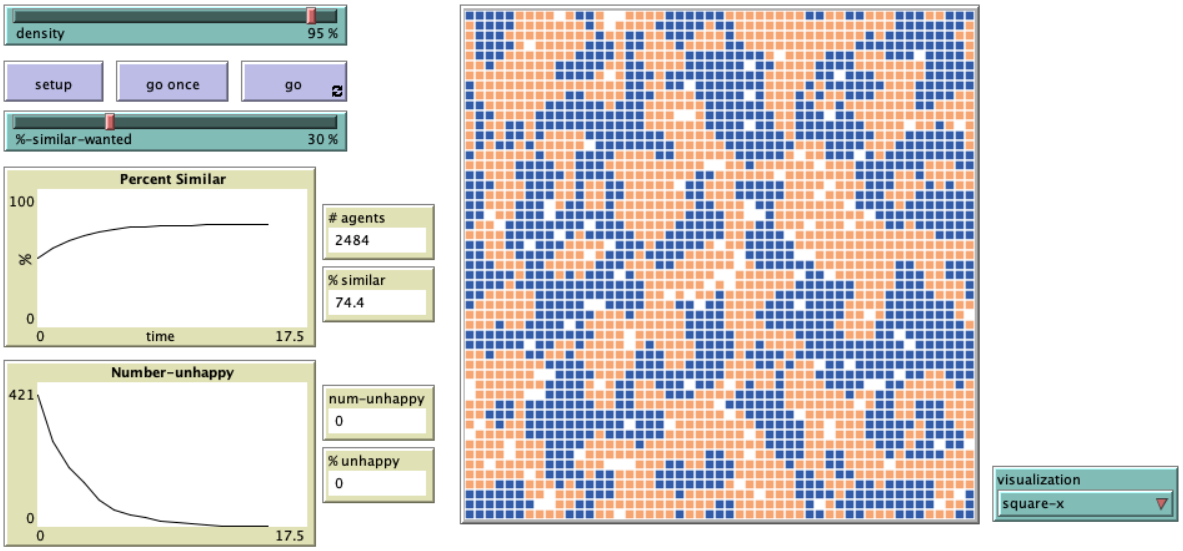
Netlogo’s interface after the simulation has been run once



By pressing on the button “go” the model will keep on running until the state of equilibrium is reached. As we can see below the unhappy agents will decrease until reaching zero, while the percentage of similar agents significantly increases.

Figure 8

Netlogo’s interface after the equilibrium has been reached



By looking at the pattern of agents on the grid we can see that agents with moderate discriminating preferences who may live peacefully in integrated communities would end up in segregated neighborhoods because they don't want to be in the minority.

We conclude that, while being based on local characteristics, the act of relocation has a global effect, because the random relocation of one agent may dissatisfy other agents who were previously satisfied.

With time, the number of unsatisfied agents decreases. However, the neighborhood grows more divided, with orange and blue agent clusters.

Finally, we can see how even modest local preferences may lead to a huge global phenomena originating from a network of individual micro-interactions using this simple model. Furthermore, these emerging macro-regularities reflect back onto individual agents, limiting their alternatives and behavior.

4.2 Extension Of Schelling's Segregation Model :Relationship Between Property Crime And Inequality

Once the empirical possible relationship between inequality and crime has been explained, we can now verify through a netlogo simulation what happens in a plausible society that features a certain percentage of criminals and where the agents living in their properties and having a randomly assigned income, can decide to relocate or stay where they are.

The simulation has been carried out in Netlogo using the Schelling segregation model as the basis, which has been explained in the previous chapter.

In the Schelling segregation model we had orange and blue turtles that had the property of belonging to two different classes of agents, in that case being two different races.

By contrast in the new simulated world are again going to appear two different types of turtles, but this time there will be the pink ones, that represent the individuals that don't engage in criminal activity, and the green ones, which are the agents that do engage in criminal activity and that are therefore criminals.
Cells in the grid represent properties characterized by a certain price where agents can live; the possibility of living in a specific property will be determined by the income of the agent.
Agents in this simulation, as well as in the schelling segregation model, feature a property named "happiness".
If in the Schelling segregation model this property was influenced by the number of non-similar individuals around a given turtle, in this model the "happiness" of the turtles is going to be influenced by the percentage of criminals around them.
Individuals that don't engage in criminal activity, which in our simulation are depicted by the pink turtles, in order to have their probability of being victim of a crime reduced, will logically prefer living in areas with a low percentage of criminals.
As well as in the Schelling segregation model, once we press the button "setup" the turtles will initially be placed randomly across the grid and consequently we will witness a certain number of happy and unhappy individuals.
Once the "go" button is pressed, unhappy turtles will relocate in unoccupied cells of the grid, but in order for an agent to be able to move in this model, it has to comply with two important characteristic:

1) It has to be situated in a patch that features the lowest possible number of neighboring criminals
2) It has to satisfy the condition $P_2 < P_1$; meaning that the price of the new property where the agent is going to move, has to be lower than the old one.
   The price of the property has been calculated as follows:

   ((count (turtles-on neighbors) + 1) - count (turtles-on neighbors) with [color = 27]) / ((count (turtles-on neighbors) + 1) - count (turtles-on neighbors) with [color = 105])

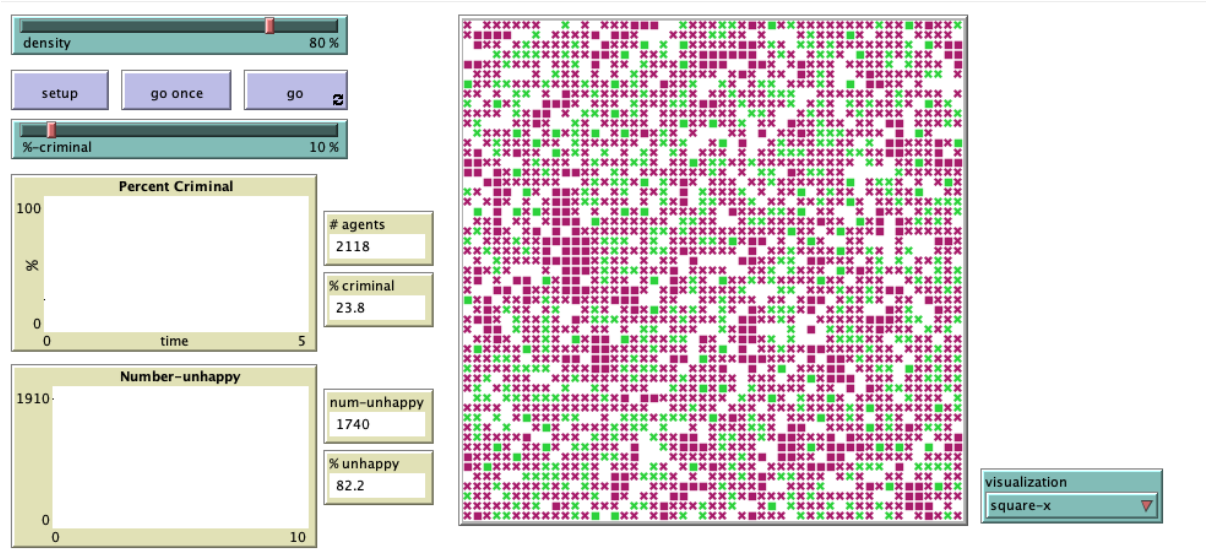
Turtles will keep on moving to new patches while unhappy and will only stop moving when they reach the state of happiness.
Ultimately, the steady state equilibrium will be reached once all the agents in the world are happy.

4.3 Netlogo Simulation Of The New Model

Once we click in the button setup, the turtles will show up in Netlogo's interface and they'll be randomly distributed in the simulated world as follows:

Figure 9

Interface of Netlogo once the new model has been setup



As we can see the density of turtles is set to 80% and the percentage of criminals, portrayed by the green squares in the model, is set to 10%.

The happy turtles are represented by squares while the unhappy turtles are easily recognizable since they are depicted by "X".

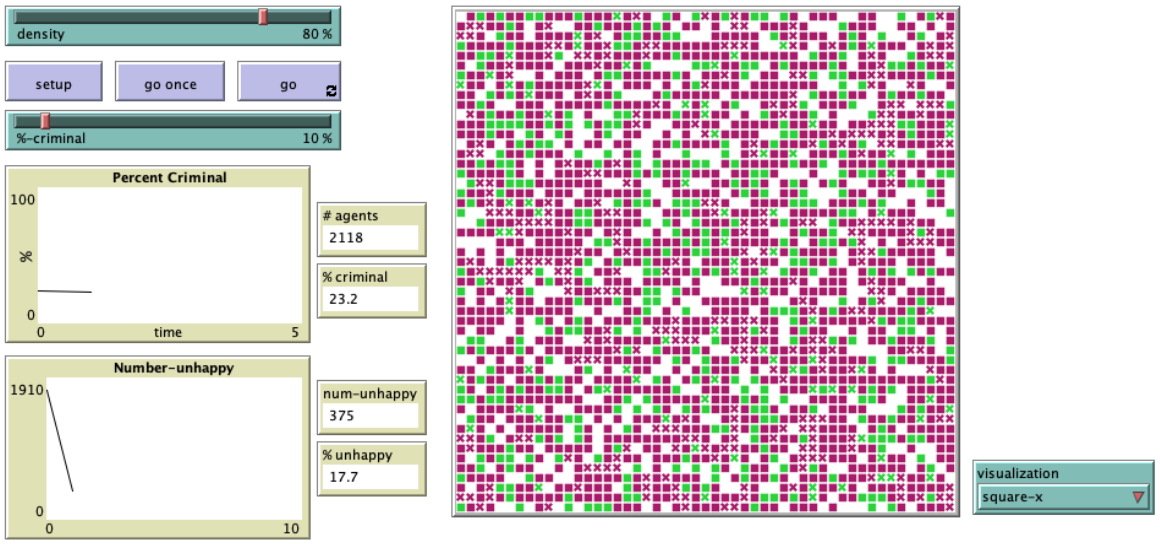
By clicking on the button "go once", we can witness what happens if we let the model run once; the unhappy turtles with enough financial possibility will be able to relocate to another patch and therefore become happy.

Consequently, as expected, what we witness is a decrease in the number of unhappy agents present in the world.

On the other hand we can't say that the equilibrium state has been reached because we can still recognize a number of unhappy agents present in the world:

Figure 10

Netlogo's interface after the simulation has been run once



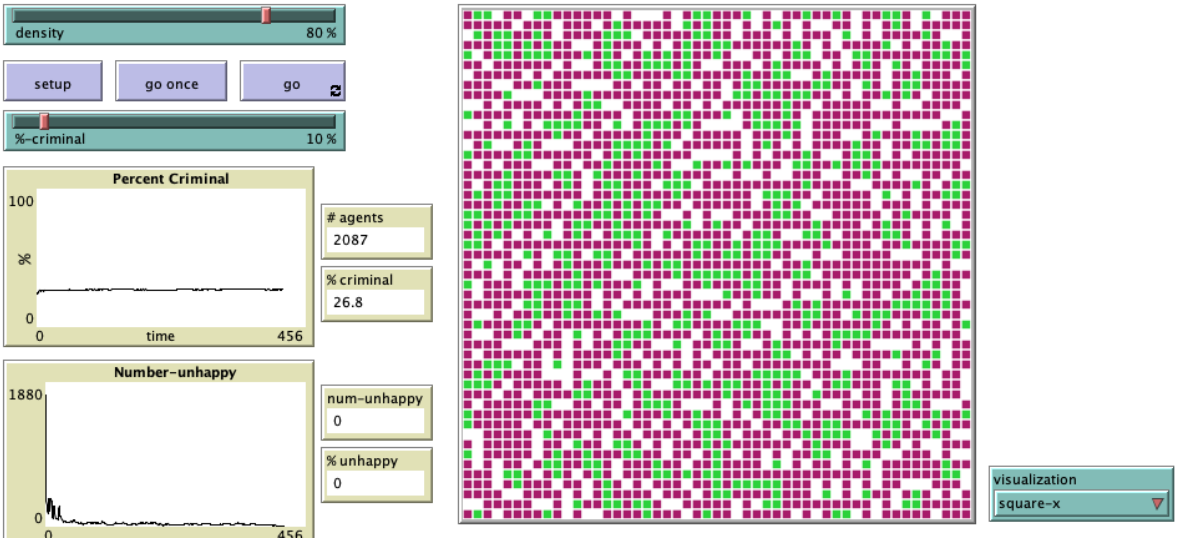
By pressing the button "go", also known as the infinity button, the model will keep on running until the equilibrium, if one exists, is reached.

In this case, when clicking on the infinity button we see how the number of unhappy individuals decreases until reaching zero, meaning we have found an equilibrium.

All of the unhappy turtles with enough financial possibility relocated to a new empty cell in the grid and no other movement can happen.

Figure 11

Netlogo's interface after the equilibrium has been reached



By looking at the image that depicts the equilibrium, there are various interesting outcomes that are worth pointing out.

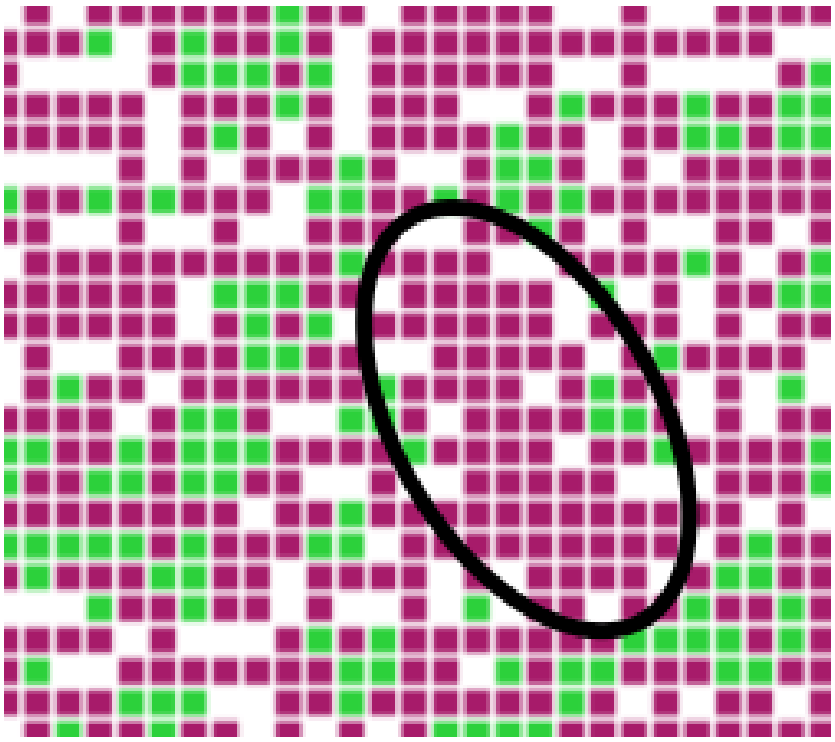
We can safely say that the agents are distributed in the model in a segregated manner, as there are various clusters of pink and green turtles across the grid.

The pink turtles with enough economic resources to relocate have moved in cells where the number of criminals around them is as low as possible, therefore we can assume that a concentration of pink agents simulates a “wealthy neighborhood”.

Below we can clearly see a part of our simulated world that comprises a rich area, where its inhabitants had enough financial possibility to live far from criminals:

Figure 12

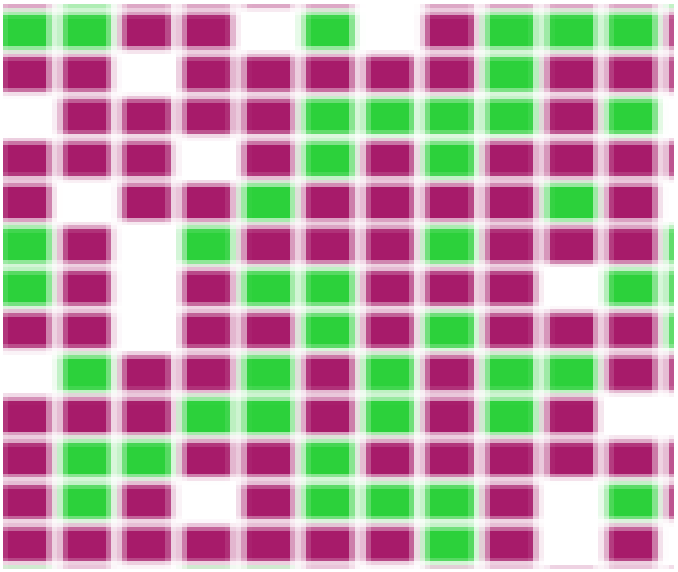
Representation of a “wealthy neighborhood”



The pink agents with limited financial resources, although they had the preference of living close to the smallest amount of criminals possible, find themselves forced to live in an area surrounded by a population of green agents, which as we have mentioned before, assume the role of criminals.

Figure 13

Representation of low income people having to live in the same neighborhood as criminals



It is indeed true that being poor or living in a poor area does not define an individual as criminal, but there are various complicated, multi-layered, interwoven, and frequently controversial issues that will lead to a rise in crime rates in disadvantaged regions.

Statistics show that people who live in impoverished neighborhoods are more likely to be involved in crime and have poorer educational, economic, and health results than those who live in less-distressed regions.

Economic research also revealed that neighborhoods may have a causal influence on individual criminality, in the sense that living in close proximity to delinquents raises people's likelihood of offending.

Because of their desperate economical situation, the probability of people living in poor neighborhoods turning into criminals are higher, and this could be due both to desperation, in the sense that disadvantaged people need money to survive and therefore would not feel as guilty when committing a crime (also because they have less to lose), but also because they are constantly exposed to criminal surroundings.

It is also important to highlight how kids and young people, growing up around criminals, are unlikely to sense the danger of committing crimes, since that reality is what they grew up around.

This simple simulation proves to us that members of society with limited financial opportunities are more likely to reside in hazardous places, increasing their own probabilities of turning into criminals, and we can therefore conclude that economic inequality is indeed positively related with crime.

5. Conclusions

Many studies that have been conducted by economists in the past have shown how inequality can indeed be considered an important determinant of crime.

It is logical to think that the reason behind this correlation lies in the fact that people who lack the basic necessities for survival would resort to illegal behaviors if they see that as the only feasible option to make a living.

Individuals with low income may be more motivated to commit a crime in communities with high disparity than in areas with equal distribution of resources because people who experience the repercussions of inequality have less to lose and are therefore more willing to break the law.

Differently from the past literature dedicated to study this relationship, which was mainly focused on econometric or empirical analysis, in this paper, the link between the two phenomena is studied through an agent based model procedure, which is an innovative type of approach that functions through a computational simulation.

As a matter of fact, to comprehend a natural or social event, it is sometimes helpful to explicitly simulate the behavior of the various elements that comprise the phenomenon.

An agent-based model, at its most basic level, is made up of a set of agents, their interactions and a landscape.

Even a simple agent-based model, characterized by agents and the way they interact, can display complicated behavior patterns and provide useful information about the dynamics of the real-world system it replicates.

To carry out the simulation we have used the software netlogo, a programmable multi-agent modeling platform that permits users to replicate a variety of natural and social phenomena.

The program was chosen because it features a low difficulty threshold for beginners and a high variety ceiling for expert programmers; it can be used for a broad range of applications, from simple investigations to complex systems.

Moreover, there is a large "models library" in Netlogo that contains a range of models already generated by other users that may be used as a basis for further modification.

The “Schelling's segregation model”, an agent-based model demonstrating how individual tendencies toward neighbors can result in segregation, has been used as a starting point for conducting the simulation, and once the code has been changed and the model appropriately modified according to the research question, we were able to come up with interesting conclusions.

As a result of our empirical analysis and thanks to the conclusion we were able to draw from the simulation, we can say that crime and inequality are indeed positively correlated**.**

6. Bibliography

Aydinonat, N. E. (2007). Models, conjectures and exploration: An analysis of Schelling's checkerboard model of residential segregation. Journal of Economic Methodology, 14, 429–454. doi:10.1080/13501780701718680

Champernowne, D. G., & Cowell, F. A. (1998). Economic Inequality and Income Distribution. Google Books. https://books.google.es/books?hl=it&lr=&id=lk5cccSd-v4C&oi=fnd&pg=PA1&dq=definition+of+economic+inequality&ots=fKMDmOWKJi&sig=IooRH2Kjb5hNRa9Mu92-vcyWMvc#v=onepage&q=definition%20of%20economic%20inequality&f=false

Cheung F, Lucas RE. Income inequality is associated with stronger social comparison effects: The effect of relative income on life satisfaction. J Pers Soc Psychol. 2016 Feb;110(2):332-41. doi: 10.1037/pspp0000059. Epub 2015 Jul 20. PMID: 26191957; PMCID: PMC4718872.

Clementi F., Valentini E., (2018), "Economia irregolare, criminalità e disuguaglianza dei redditi: un circolo vizioso?", Moneta e Credito, 71

Groff, E. R. (2018, February 23). State of the Art in Agent-Based Modeling of Urban Crime: An Overview. SpringerLink.
Kang, S. Inequality and crime revisited: effects of local inequality and economic segregation on crime. J Popul Econ 29, 593–626 (2016). https://doi.org/10.1007/s00148-015-0579-3

McGregor, T., Smith, B., & Wills, S. (2019, July 11). Measuring inequality. OUP Academic. https://academic.oup.com/oxrep/article-abstract/35/3/368/5531388?redirectedFrom=full text

Piketty, T., & Rendall, S. (2022). A Brief History of Equality. Belknap Press: An Imprint of Harvard University Press.
Platas-López, A. (2021, January 31). On the Macroeconomic Effect of Extortion: An Agent-Based Approach. Journal of Artificial Societies and Social Simulation. https://www.jasss.org/24/1/3.html

Schelling, T. C. (1969). Models of segregation. American Economic Review, 59, 488–493. Retrieved from http://www.jstor.org/stable/1823701

Schelling, T. C. (1971a). Dynamic models of segregation. Journal of Mathematical Sociology, 1, 143–186. doi:10.1080/0022250X.1971.9989794

7. Appendix

The code of Schelling's segregation model has been modified in the following way:

```
globals [
  percent-criminal
  ;percent-similar  ; on the average, what percent of a turtle's neighbors
                     ; are they the same color as that turtle?
  percent-unhappy  ; what percent of the turtles are unhappy?
  average-property-price
]

turtles-own [
  happy?          ; for each turtle, indicates whether at least %-similar-wanted percent of
                  ;   that turtle's neighbors are the same color as the turtle
  criminal-nearby
  ;similar-nearby   ; how many neighboring patches have a turtle with my color?
  other-nearby     ; how many have a turtle of another color?
  total-nearby     ; sum of previous two variables
  property-price
  ;new-property-price
]

to setup
  clear-all
  ; create turtles on random patches.
  ask patches [

    set pcolor white
    if random 100 < density [   ; set the occupancy density
      sprout 1 [
        ; 105 is the color number for "blue"
        ; 27 is the color number for "orange"
        set color one-of [105 105 105 27]
        set size 1
      ]
    ]
  ]
  update-turtles
  update-globals
  reset-ticks
end
```

```
; run the model for one tick
to go
  if all? turtles [ happy? ] [ stop ]
  move-unhappy-turtles
  update-turtles
  update-globals
  tick
end

; unhappy turtles try a new spot
to move-unhappy-turtles
  ask turtles with [ not happy? ]
    [ find-new-spot ]
end

; move until we find an unoccupied spot
to find-new-spot
  rt random-float 360
  fd random-float 10
   ;set new-property-price ((count (turtles-on neighbors) + 1) - count (turtles-on neighbors) with [ color = 27]) / ((count (turtles-on neighbors) + 1) - count (turtles-on neighbors)  with [ color = 105])
  if any? other turtles-here [ find-new-spot ] ; keep going until we find an unoccupied patch
  ;if new-property-price > property-price [ find-new-spot ]
  move-to patch-here  ; move to center of patch
end

to update-turtles
  ask turtles [
    ; in next two lines, we use "neighbors" to test the eight patches
    ; surrounding the current patch
    ;set similar-nearby count (turtles-on neighbors)  with [ color = [ color ] of myself ]
    set criminal-nearby count (turtles-on neighbors)  with [ color = 27 ]
    set other-nearby count (turtles-on neighbors) with [ color = 105 ]
    set total-nearby criminal-nearby + other-nearby
     set property-price ((count (turtles-on neighbors) + 1) - count (turtles-on neighbors)  with [ color = 27]) / ((count (turtles-on neighbors) + 1) - count (turtles-on neighbors)  with [ color = 105])
       set happy? (criminal-nearby < (%-criminal * total-nearby / 100)) or (property-price < average-property-price)
    ; add visualization here
    if visualization = "old" [ set shape "default" set size 1.3 ]
    if visualization = "square-x" [
      ifelse happy? [ set shape "square" ] [ set shape "X" ]
    ]
  ]
end
```

```
to update-globals
  let criminal-neighbors sum [ criminal-nearby ] of turtles
  let total-neighbors sum [ total-nearby ] of turtles
  set percent-criminal (criminal-neighbors / total-neighbors) * 100
  set percent-unhappy (count turtles with [ not happy? ]) / (count turtles) * 100
  set average-property-price mean [property-price] of turtles
end
```