# Introduction

## Aims and Objectives

The model will compare the different rates at which wealth is increasing, vs the corresponding increase in income, i.e., how much money is returned by simply investing or collecting interest on pre-existing money or assets vs the equivalent amount of money that is returned from wages for work. It will also include various other factors that may affects these amounts, such as taxes/tax breaks, welfare programs alleviating costs, the rate of return on capital and the nominal economic growth rate.

The focus will be on the percentage rate of returns for capital and income, as well as modelling expenses for an average person. Sliders will also be included for different tax rates and a universal basic income option that will remove the cost of living from the equation. Different populations and proportions of each class will also be modelled to see if this has any bearing on the outcomes.

The goal of the model is to represent the vast differences in earning ability between those with capital and those who engage in labour for their incomes. We also want to find out if there is any combination of variables that will be able to alleviate this disparity, not by simply switching it around but by finding a way that both earning abilities can sit at roughly the same level, while also being higher than the initial income return rate.

If Thomas Piketty’s theory is correct, then you would expect that when variables like those in the real world are input into the model that the money returned from capital would quickly overtake that returned from income. It is also expected that the total share of wealth will be consolidated into one class unless the variables are massively adjusted from their current real-world values.

## Background

The idea for this model is based off Thomas Piketty’s thesis in Capital in the 21st Century which is as follows:

1. The ratio of wealth to income is rising in all developed countries.
2. Unless extreme measures are taken this trend will likely continue.
3. If it continues, the future will begin to resemble the 19th century, where the majority of economic elites inherited their wealth rather than working for it.
4. His proposed best solution would be a globally coordinated effort to tax wealth.

The basic concept is that the wealth-to-income ratio and the comparison of the rate of return on capital (represented as **r**) to the rate of nominal economic growth (**g**, representing the increase in wages caused by economic growth).

The rate of return on capital is a somewhat abstract idea, although an example would be as follows: If you invest £100 in an enterprise and it returns you £10 a year in income then your rate of return would be 10%.

In the context of this model **r** is the rate of return on all investments combined. One of the main points the book asserts is that the average **r** is 6% regardless of the state of the economy, meaning that if **g** is less than 6% then the wealth of the already wealthy will grow faster than the economy as a whole. In practice g has been below 6% the past few decades, with this trend expected to continue.

# Results of Analysis

## Comparing the Effect of Universal Basic Income with present day model parameters

Graphical user interface, chart

Description automatically generated

It can be seen that without universal income that the wealth of the upper class explodes exponentially, while both the lower and middle classes wealth slowly drains away due to the constant increase in the cost of living. This is also reflected in the population of each class, with the lower and middle classes initially showing a slight bump in their population before decreasing at an exponential rate, while the upper class grow from a tiny population to bigger than any original population before hitting a peak and beginning to slowly decline. However, with UBI present all populations are able to increase at equally steady rates, and despite the upper-class wealth still decreasing much faster, both the middle and lower classes are able to grow together at a steady rate.

## Comparing different tax rates on the Upper classes

Graphical user interface, chart, histogram

Description automatically generated

By increasing the tax rate on the upper-class it can be seen that their population doesn’t explode to the same extent, with a tax rate of 70%+ keeping them in the same range as the lower- and middle-class population.

Chart

Description automatically generated

Meanwhile their wealth is unable to grow to the same level as the tax rate increases, dropping by nearly a factor of 10 as the tax rate increases. It however still takes nearly 15000 days (over 41 years) of a 100% tax rate for the upper-class wealth to reach the same level as the lower class. Meanwhile the middle class’s wealth decreases at the same rate irrespective of the tax rate.

## Comparing adjustments to the rate of economic growth

Chart

Description automatically generated

Chart

Description automatically generated

Oddly increasing the rate at which the economy grows has almost no effect on the rate at which the lower class and middle-class populations or share of wealth change, as their cost of living is increasing proportionally to the wages they are able to earn. For the upper class however, there is a marked difference in how their population and wealth changes based on the economic growth rate:

* With a 0% growth rate their population and wealth share rapidly increase before ultimately levelling off.
* At a 3% growth rate (roughly the current value) their wealth shoots up before slowly decreasing after the 10,000-day mark.
* At a 6% growth rate (equal to the current return on investment rate), there is much more marked decrease in the population and wealth of the upper class at the same point it begins to decrease in the 3% model.
* Finally at a 12% growth rate (roughly twice that of the rate of return on investment) results in a sharp increase at the start, before decreasing rapidly until it reaches a level comparable to the population and wealth of the other two classes

# Conclusions

* In most variations of the model after a set amount of time has passed, the lower and middle class converge in terms of the amount of wealth each class owns. Meanwhile the proportion of wealth owned by the upper class increases exponentially, until they are the only class left at which point their wealth and population begins to slowly decline.
* When the cost of living is removed from the equation via universal benefits, the lower and middle class can slowly increase their share of the total wealth, and despite not reaching the heights of the upper class they also do not exhaust their wealth and die out within the span of 100 years in the model. Surprisingly, the Upper Class also do not die out despite the fact they are minimally affected by the cost of living. This would seem to support Piketty’s theory.
* However, this model is a grossly simplified version of the real world and there are several ways in which it could be improved. If I had more time to work on it, I would like to implement the following:

1. Have the taxes paid by each agent be assigned to a ‘Government’ agent which can reassign it to other agents periodically based on their wealth.
2. Break down living costs into separate parts that must be paid at different intervals. I would also include a random variation on each cost to better reflect the real world.
3. Add the ability for middle- and upper-class agents to own certain job patches, and therefore charge rent or implement some other sort of wealth exchange between them and any agent that harvests that patch.
4. Add the ability for parent and offspring to work as a collective so inherited wealth can be better examined by comparing families within classes against one another

# Appendix: ODD Protocol

**1. Purpose**

Model aims to compare the different rates at which wealth is increasing, vs the corresponding increase in income, i.e., how much money is returned by simply investing or collecting interest on pre-existing money or assets vs the equivalent amount of money that is returned from wages for work. It will also include various other factors that may affects these amounts, such as variable tax rates for each class, welfare programs alleviating costs, the rate of return on capital and the nominal economic growth rate. The idea for this model is based on the key concepts behind economist Thomas Piketty’s research in Capital in the Twenty First Century.

The model will mainly focus on the rate at which the economy grows and the percentage rate of returns for capital and income, as well as modelling expenses for an average person. Sliders are also included for different tax rates and a universal basic income option that will remove the cost of living from the equation.

The goal of the model is to represent the vast differences in earning ability between those with capital and those earning incomes. It also aims to find out if there is any combination of variables that will be able to alleviate this disparity, not by simply switching it around but by finding a way that both earning abilities can sit at roughly the same level, while also being higher than the initial income return rate.

**2. Entities, state variables, and scales**

"The entities in this model are members of three distinct classes (represented by turtles) and job alternatives (represented by patches) that vary in the wages they pay.  
The turtles have the following [state] variables:  
• their location in space (primitives xcor and ycor),  
• their current wealth (in GBP)  
• the amount of labour they carry out a day (ranging from 0 to 12 hours based on the turtles class)  
• age - how old a turtle is in days  
• life-expectancy (the maximum age that a turtle can reach)  
• capital- this is the amount of wealth a turtle sets aside for investing per year. After investing it is then added to the turtle’s wealth  
• tax-rate- the amount each turtle loses to taxes, with a different tax rate for each class  
• vision- how many patches ahead a turtle can see, this determines how far they can travel for jobs.

The landscape is a grid of potential jobs, each of which has two static [state] variables: the current wages that the patch pays out (in the same money units) and the maximum amount of wages that this patch can hold. This landscape is 32 x 32 patches in size.

The model time-step is 1 day, and simulations run for 50 years."

**3. Process overview and scheduling**

The model has the following actions which take place over two distinct time scales.

The following actions take place each tick (representing a day):

The agents each turn towards the patch with the best paying job in their vision. They then approach it as quickly as possible and extract wages from it. The wages are split evenly between all the agents on the patch at the time they ‘harvest’ wages. These wages are then multiplied by the agents’ labour variable to determine the amount of wealth they make each tick. After increasing their wealth via wages, the agents are then deducted their cost of living. This is equal to the median cost of living in the UK.

After each tick the patches wages are reinitialised with a random amount of wages between the minimum and maximum wage currently available at the time. Finally, at the end of each tick the model checks to see if any agents have reached their maximum life expectancy or hit a wealth of 0, at which point they die.

Additionally, the outputs, view and plots are updated with each tick.

Meanwhile the following actions occur every 365 ticks (representing a year):

The economy grows according to the value set in the growth-of-economy variable. This causes the minimum and maximum wages to increase by the same percentage as the variable, while the cost of living also increases.

The agents undergo several procedures at the end of each year:  
• Their age increases by 1  
• Each agent has a 25% chance to reproduce and create an offspring with half their wealth and capital, as well as the initial state variables of their class  
• Each agent is taxed according to their class bracket. By default, this is 15, 25 and 40% percent respectively  
• Agents from the middle and upper-class receive a return on their capital equal to the return-on-investment variable. This capital is then added to their wealth before they set aside a percentage of their new wealth to use as capital for the next cycle.

**4. Design concepts**

Basic principles: The inherent idea is based off Thomas Piketty’s thesis in Capital in the 21st Century which is as follows:

• The ratio of wealth to income is rising in all developed countries.  
• Unless extreme measures are taken this trend will likely continue.  
• If it continues, the future will begin to resemble the 19th century, where most economic elites inherited their wealth rather than working for it.  
• His proposed best solution would be a globally coordinated effort to tax wealth.

The basic concept is that the wealth-to-income ratio and the comparison of the rate of return on capital (represented as r) to the rate of nominal economic growth (g, representing the increase in wages caused by economic growth).

Emergence: The model’s main output is the share of total wealth that each class owns, based on adjusting g and r, as well as other factors such as the taxation rates for each class, the initial amount of money each member of a class starts with and the amount they pass on to their offspring. This output changes based on the amount of wages being collected as well as the amount of money each class member can set aside for investment, with it being expected that outside of extreme scenarios the share of total money owned by the upper class will increase, albeit at different speeds.

Adaptive behaviour: The adaptive behaviour of agents is repositioning: the decision of which nearby jobs to move to (or whether to stay put), considering the wages they are currently making and the number of agents they must split it with. Each time-step, agents can reposition to any jobs nearby (within their sensing-radius) or retain their current position.

Objective: Members of the lower and middle class seek to locate the best paying job to acquire enough wealth to afford their living costs for each tick, whilst also having enough money to pass onto their offspring to ensure both their survival. The amount of wages they receive is based on the below equation:

∆Wealth = Wages \* Labour

Meanwhile members of the upper class have no such objective as most of their wealth comes from their inherited wealth and the annual rate of return on their wealth according to the below equation:

Wealth = Wealth + (Capital \* Rate-of-Return)

As a result, the upper class’s wealth is expected to increase exponentially in comparison to that of the other classes.

Prediction: The model estimates the population and share of wealth for each class at each time step. This is possible because the rate at which their wealth increases is constant, and the chance of a given class member reproducing is also static.  
Sensing: The class members are assumed to know the location of the patches with the best paying jobs, without error.

Interaction: The class members interact with each other only indirectly via competition for wages; the number of wages on a patch is divided evenly amongst the agents on a patch during each time step so it is in a agent’s interest to find a high value patch with no other agents on it. Upper class agents actively drive wages down, especially as many of them receive no new wealth from a patch due to their having a labour value of 0.

Stochasticity. The initial state of the model is stochastic: the maximum and actual wages of each job (patch), and agent locations, as well as their attributes, are set randomly. Stochasticity is thus used to simulate an environment in which class members with different amounts of initial wealth, work ability and ability to seek jobs are present. Agents have a random chance to either die or reproduce at a given time step and patches are replenished by a random amount of wages between their minimum and maximum potential every other time step.  
Observation: The View shows the location of each agent on the work landscape. Graphs show population of each class at a given time step, as well as the amount of wealth each class owns and the share of the total wealth this represents.

Learning and Collectives are not part of this model.

**5. Initialisation**

The maximum wage potential of a given patch is determined from a range between the minimum wage (£8.91) and the maximum wage available (initially this is £273.97). The wages are then spread around each patch that has the maximum wage to ensure a gradient of various wages is present.

A number of agents of each class, proportional to the percentage of the total population, are initialised and placed at random patches. They are then given random variables, within a set range for their class.

**6. Submodels**

Vision, which describes the maximum distance (or difference from) their current job that agents can detect the value of other patches and move towards them.

Agent repositioning. An agent determines whether they can achieve higher wages at a different patch to the one they are at. If they can they move towards this patch, otherwise they remain at their current patch.

Economic Activity. This event is a combination of the economic growth rate, the rate of return and the tax rates for each class. This adjusts the wealth, wages and cost of living for all agents at a regular time interval.

**RELATED MODELS**

This model is based on the Sugarscape Wealth Distribution Model included in the Netlogo Model Library

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