

Table 1. GDP, Tax & Welfare Data for simulating the economies of Aust, US & UK

Date	Country	Tax-Collected as-%-of-GDP	Welfare Payment to-Reds	Gini	WGT	WGV
2009-10	Australia	0.13	0.52	0.33	6.00	10.00
2010-11	Australia	0.13	0.51	0.33	6.00	10.00
2011-12	Australia	0.15	0.49	0.32	6.00	10.00
2012-13	Australia	0.15	0.49	0.33	6.00	10.00
2013-14	Australia	0.15	0.51	0.34	6.00	10.00
2014-15	Australia	0.15	0.50	0.33	6.00	10.00
2015-16	Australia	0.15	0.49	0.32	6.00	10.00
2016-17	Australia	0.16	0.46	0.32	6.00	10.00
2017-18	Australia	0.17	0.41	0.33	6.00	10.00
2018-19	Australia	0.18	0.38	0.34	6.00	10.00
2009-10	USA	0.26	0.15	0.47	9.00	10.00
2010-11	USA	0.27	0.14	0.48	9.00	10.00
2011-12	USA	0.26	0.14	0.48	9.00	10.00
2012-13	USA	0.28	0.13	0.48	9.00	10.00
2013-14	USA	0.29	0.13	0.48	9.00	10.00
2014-15	USA	0.29	0.13	0.48	9.00	10.00
2015-16	USA	0.29	0.13	0.48	9.00	10.00
2016-17	USA	0.28	0.13	0.48	9.00	10.00
2017-18	USA	0.28	0.13	0.49	9.00	10.00
2018-19	USA	0.27	0.13	0.48	9.00	10.00
2009-10	UK	0.26	0.35	0.37	3.00	9.00
2010-11	UK	0.27	0.34	0.34	3.00	9.00
2011-12	UK	0.28	0.33	0.34	3.00	9.00
2012-13	UK	0.27	0.35	0.34	3.00	9.00
2013-14	UK	0.26	0.33	0.35	3.00	9.00
2014-15	UK	0.27	0.32	0.35	3.00	9.00
2015-16	UK	0.27	0.32	0.35	3.00	9.00
2016-17	UK	0.27	0.30	0.33	3.00	9.00
2017-18	UK	0.28	0.30	0.34	3.00	9.00
2018-19	UK	0.28	0.30	0.35	3.00	9.00

WHAT IS IT?

This model simulates the distribution of wealth. “The rich get richer and the poor get poorer” is a familiar saying that expresses inequity in the distribution of wealth. In this simulation, we see Pareto’s law, in which there is a large number of “poor” or RED people, fewer “middle class” or GREEN people, and many fewer “rich” or BLUE people.

HOW IT WORKS

This model is adapted from Epstein & Axtell’s “Sugarscape” model. It uses grain instead of sugar. Each patch has an amount of grain and a grain capacity (the amount of grain it can grow). People collect grain from the patches and eat the grain to survive. How much grain each person accumulates is his or her wealth.

The model begins with a roughly equal wealth distribution. The people then wander around the landscape gathering as much grain as they can. Each person attempts to move in the direction where the most grain lies. Each cycle is termed TICK. TIME is represented as the number of ticks. During each time tick, each person eats a certain amount of grain. This amount is called their Metabolism. People also have a Life Expectancy. When their lifespan runs out, or they run out of grain, they die and produce a single offspring. The offspring has a random metabolism and a random amount of grain, ranging from the poorest person’s amount of grain to the richest person’s amount of grain (There is no inheritance of wealth).

To observe the equity (or the inequity) of the distribution of wealth, a graphical tool called the Lorenz curve is utilised. We rank the population by their wealth and plot the percentage of the population that owns each percentage of the wealth (e.g. 30% of the wealth is owned by 50% of the population). Hence the ranges on both axes are from 0% to 100%.

Another way to understand the Lorenz curve is to imagine a society of 100 people with a fixed amount of wealth available. An individual is 1% of the population. Rank the individuals in order of their wealth from greatest to least: the poorest individual would have the lowest ranking of 1 and so forth. Then plot the proportion of the rank of an individual on the y-axis and the portion of wealth owned by this individual and all the individuals with lower rankings on the x-axis. For example, individual Y with a ranking of 20 (20th poorest in society) would have a percentage ranking of 20% in a society of 100 people (or 100 rankings) — this is the point on the y-axis. The corresponding plot on the x-axis is the proportion of the wealth that this individual with ranking 20 owns along with the wealth owned by all the individuals with lower rankings (from rankings 1 to 19). A straight line with a 45-degree incline at the origin (or slope of 1) is a Lorenz curve that represents perfect equality — everyone holds an equal part of the available wealth. On the other hand, should only one family or one individual hold all of the wealth in the population (i.e. perfect inequity), then the Lorenz curve will be a backwards “L” where 100% of the wealth is owned by the last percentage proportion of the population. In practice, the Lorenz curve actually falls somewhere between the straight 45-degree line and the backwards “L”.

For a numerical measurement of the inequity in the distribution of wealth, the Gini index (or Gini coefficient) is derived from the Lorenz curve. To calculate the Gini index, find the area between the 45-degree line of perfect equality and the Lorenz curve. Divide this quantity by the total area under the 45-degree line of perfect equality (this number is always 0.5 — the area of 45-45-90 triangle with sides of length 1). If the Lorenz curve is the 45-degree line, then the Gini index would be 0; there is no area between the Lorenz curve and the 45-degree line. If, however, the Lorenz curve is a backwards “L”, then the Gini-Index would be 1 — the area between the Lorenz curve and the 45-degree line is 0.5; this quantity divided by 0.5 is 1. Hence, equality in the distribution of wealth is measured on a scale of 0 to 1 — more inequity as one travels up the scale. Another way to understand (and equivalently compute) the Gini index, without reference to the Lorenz curve, is to think of it as the mean difference in wealth between all possible pairs of people in the population, expressed as a proportion of the average wealth (see Deltas, 2003 for more).

THE COUNTERBALANCE ECONOMICS (CBE) MODEL

The Counterbalance Economics system is the name of an alternative economic system which aims to reduce the level of inequality in any given population.

The Wealth Distribution model has been updated to incorporate the key elements of the Counterbalance system which are:

1. Paying the lowest paid workers, the AWE (Average Weekly Earnings) or Average total wealth in this model
2. Paying the lowest 50% of workers does not reduce the amount of grain available, to simulate paying those workers with Contra-deal credits
3. This also simulates how the Counterbalance model fixes supply shortages without damaging the environment

Note: The Counterbalance Economics model reduces inequality to almost zero, which means there is no poverty, while still allowing the rich to remain rich.

The model aims to complement capitalism, not replace it. It aims to work with current systems to rebalance and provide and equal opportunity for all.

One of the goals of the update to this Agent Based Model, was to allow the simulation of any global economy which includes their economic and inequality levels and then compare those to the levels that would exist if we incorporated the CBE system into their existing economic system. To achieve this, we have added the following four sliders and one chooser.

Tax-Collected-as-%-of-GDP (slider) – Allows simulation of the amount of tax collected by different countries as a percentage to their GDP

Welfare-Payment-to-Reds (slider) – Allows the simulation of the amount of welfare payments as a percentage of taxes collected (Welfare is only paid to the lowest class in the model, the Reds)

Wealth-Growth-Time (slider) – Allows the simulation of how quickly an economy is growing

Wealth-Growth-Volume – Allows the simulation of the volume of growth occurring in an economy

The last 2 sliders allow simulation of the business cycle (more commonly known as “booms and busts”). A “business cycle ... refers to the alternating periods of expansion and contraction in economic activity relative to the trend in the economic growth rate that the economy experiences over time” (Hubbard, p190).

Economic-System (chooser) – Allows us to choose between the “original model” that the ABM came with, the “Counterbalance” model which provides a comparison between the status quo and the addition of the CBE to that particular economic system and the “Neoliberal-v-GovernmentRun” model which allows us to simulate any global economy using the four sliders just discussed.

This is possible because all global economies have the following 3 attributes:

- a level of GDP
- a level of taxation and
- a level of social welfare (if no social welfare is provided, simply set the slider to zero).

For an economy to exist, there must be a market to allow the sale of goods and services. The key difference between each country is what level of control or freedom the government allows, via regulation. It can therefore be said that the key difference between all economies is their position on the level of regulation spectrum. On one end, with the most regulation, includes Keynesianism, Socialism and Communism. At the other end of the spectrum, with the least amount of regulation, we have mixed market economies and Neoliberal economies (Heywood 2013, 145). This then determines the amount of taxation that is required to pay government employees to administer the regulation and to provide the safety net being provided. This is simulated in the Wealth Distribution model with the Tax-Collected-as-%-of-GDP and the Welfare-Payment-to-Reds sliders.

For a complete overview of the Counterbalance Economics system, please go to www.UrReferendum.org.au

HOW TO USE IT

The PERCENT-BEST-LAND slider determines the initial density of patches that are seeded with the maximum amount of grain. This maximum is adjustable via the MAX-GRAIN variable in the SETUP procedure in the procedures window. The GRAIN-GROWTH-INTERVAL slider determines how often grain grows. The NUM-GRAIN-GROWN slider sets how much grain is grown each time GRAIN-GROWTH-INTERVAL allows grain to be grown.

The NUM-PEOPLE slider determines the initial number of people. LIFE-EXPECTANCY-MIN is the shortest number of ticks that a person can possibly live. LIFE-EXPECTANCY-MAX is the longest number of ticks that a person can possibly live. The METABOLISM-MAX slider sets the highest possible amount of grain that a person could eat per clock tick. The MAX-VISION slider is the furthest possible distance that any person could see.

GO starts the simulation. The TIME ELAPSED monitor shows the total number of clock ticks since the last setup. The CLASS PLOT shows a line plot of the number of people in each class over time. The CLASS HISTOGRAM shows the same information in the form of a histogram. The LORENZ CURVE plot shows the Lorenz curve of the population at a particular time as well as the 45-degree line of equality. The GINI-INDEX V. TIME plot shows the Gini index at the time that the Lorenz curve is drawn. The LORENZ CURVE and the GINI-INDEX V. TIME plots are updated every 5 passes through the GO procedure.

- - "Red #", "Green #" and "Blue #" monitors show the number of persons in each class (poor/middle/rich).
- - "AvgRd", AvgGrn and AvgBlu monitors show the average for each class (the total earned by the group / total in the group).
- - "Avg Total Wealth" monitor shows the average wealth of all persons.
- - "Wealth in the World/Country" monitor shows the total wealth in the economy, which includes all the grain wealth on the land and the grain wealth owned by the population.
- - "Taxes" monitor shows the amount of tax being deducted from the population at each tick.
- - "Welfare Payments" monitor, show the total amount of welfare being paid to red population
- - "Gini monitor" shows the level of inequality that exists in the simulation at any given period

SIMULATING AN ECONOMY

To simulate an economy, you need to have a set of data to work with including a countries GDP, Total Tax Revenue, Welfare Payments and Gini index for the year/s you want to simulate.

You then need to calculate the two numbers that you input into the system which are:

1. The percentage of Tax to GDP (Adjust Tax-Collected-as-%-of-GDP slider to that setting)
2. The percentage of Welfare Payments to Tax Revenue (Adjust Welfare-Payment-to-Reds slider to that setting)

Finally, once you set the values calculated, you run the model several times and adjust the Wealth-Growth-Time (WGT) and the Wealth-Growth-Volume (WGV) sliders until you can achieve the highest Gini and the lowest Gini index numbers in your data set. This will allow the simulation of the level of growth or lack of in the model economy. To provide further clarification of how this works, we have provided the sample data used to simulate the economies of Australia, US, and the UK from 2010 to 2019 in the table 1. Below.

Example: To simulate Australia, we first set our Tax-Collected to 0.18 and the welfare setting to 0.38 (2018/19 figures) and then adjust the WGT and WGV sliders until we achieved a .34 Gini (highest Gini score) at the end of a simulation run. We then repeat this process adjusting the Tax-Collected to 0.15 and welfare to 0.49 (2011/12 figures) and once again adjusted the WGT and WGV until we achieved a 0.32 Gini (lowest Gini score). We would have found the WGT and WGV setting for a country when we can achieve both the high Gini and low Gini values by only adjusting the tax-collected and welfare paid for any particular year. For Australia, we found that this occurs when the WGT is set to 6 and the WGV is set to 10. Please note that the Gini level calculated by the Wealth Distribution model occurs as a result of running the model. This means that although the more accurate it is the better, it is ok if the model fluctuates between a Gini score of 0.31 and 0.33 for 2011/12 and between 0.33 and 0.35 for 2018/19.

Generally, we would start both sliders at 10 and then adjust the WGT back towards 1, 1 increment at a time. Once you have found a setting for the WGT, adjust the WGV one increment up or down to achieve a higher accuracy if required. At this point the model has been primed for that particular country which will allow you to test how an economy has performed in any given year as well as testing to see how it would have performed had the CBE model been added to the economy for that year.

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2017-18	UK.....	0.28	0.30	0.34	3.00	9.00
2018-19	UK.....	0.28	0.30	0.35	3.00	9.00

Note: data is easier to read in edit mode or copied into Excel

CBE COMPARISON SUMMARY

The goal for updating the Wealth Distribution model was to simulate any global economic system to allow a comparison between what is and how any economy is likely to be affected with the introduction of the CBE system.

To achieve this we implemented the use of sliders to simulate the level of GDP, Taxation, Welfare spending for any economy and a method for approximating the business cycle by ensuring that the model is able to replicate the highest and lowest Gini index value for the test country being studied.

Based on the simulation, introducing the CBE into the Australian, UK or US economies would increase the overall wealth of those countries by around 492% and the level of inequality would be reduced from an average of .384 down to an average of .07. Further research will be conducted which includes a pilot to test the robustness of the results achieved in the simulation.

THINGS TO NOTICE

Notice the distribution of wealth. Are the classes equal?

This model usually demonstrates Pareto's Law, in which most of the people are poor, fewer are middle class, and very few are rich. Why does this happen? Do poor families seem to stay poor? What about the rich and the middle-class people?

Watch the CLASS PLOT to see how long it takes for the classes to reach stable values.

As time (ticks) passes, does the distribution get more equalised or more skewed? (Hint: observe the Gini index plot)

Try to find resources from the U.S. Government Census Bureau for the U.S.'s Gini coefficient. Are the Gini coefficients that you calculate from the model comparable to those of the Census Bureau? Why or why not?

Is there a trend in the plotting of the Gini index with respect to time? Does the plot oscillate? Or does it stabilise to a certain number?

THINGS TO TRY

Are there any settings that do not result in a demonstration of Pareto's Law?

Play with the NUM-GRAIN-GROWN slider and see how this affects the distribution of wealth.

How much does the LIFE-EXPECTANCY-MAX matter?

Change the value of the MAX-GRAIN variable (in the setup procedure in the Code tab). Do outcomes differ?

Experiment with the PERCENT-BEST-LAND and NUM-PEOPLE sliders. How do these affect the outcome of the distribution of wealth?

Try having all the people start in one location. See what happens.

Try setting everyone's initial wealth as being equal. Does the initial endowment of an individual still arrive at an unequal distribution in wealth? Is it less so when setting random initial wealth for individuals?

Try setting all the individuals' wealth and vision to being equal. Do you still arrive at an unequal distribution of wealth? Is it more equal in the measure of the Gini index than with random endowments of vision?

EXTENDING THE MODEL

Have each newborn inherit a percentage of the wealth of its parent.

Add a switch or slider which has the patches grow back all or a percentage of their grain capacity, rather than just one unit of grain.

Allow the grain to give an advantage or disadvantage to its carrier, such as every time some grain is eaten or harvested, pollution is created.

Would this model be the same if the wealth were randomly distributed (as opposed to a gradient)? Try different landscapes, making SETUP buttons for each new landscape.

Try allowing metabolism or vision or another characteristic to be inherited. Will we see any sort of evolution? Will the "fittest" survive? If not, why not?

We said above that "there is no inheritance of wealth" in the model, but that is not entirely true. New babies are born (termed "turtles" in ABM) in the same location as their parents. If grain is plentiful relative to the population at this location, they inherit a good starting situation. Try moving the turtles to a random patch when they are born. Does that lead to a more equitable distribution of wealth?

Try adding in seasons into the model. That is to say: have the grain grow better in a section of the landscape during certain times and worse at others.

How could you change the model to achieve wealth equality?

The way the procedures are set up now, one person will sometimes follow another. You can see this by setting the number of people relatively low, such as 50 or 100, and having a long-life expectancy. Why does this phenomenon happen? Try adding code to prevent this from occurring. (Hint: When and how do people check to see which direction they should move in?)

NETLOGO FEATURES

Examine how the landscape of color is created — note the use of the scale-color reporter. Each patch is given a value, and scale-color reports a color for each patch that is scaled according to its value.

Note the use of lists in drawing the Lorenz Curve and computing the Gini index.

CREDITS AND REFERENCES

This model is based on a model described in Epstein, J. & Axtell R. (1996). *Growing Artificial Societies: Social Science from the Bottom Up*. Washington, DC: Brookings Institution Press.

For an explanation of Pareto's Law, see https://en.wikipedia.org/wiki/Pareto_principle.

For more on the calculation of the Gini index see:

- Deltas, George (2003). The Small-Sample Bias of the Gini Coefficient: Results and Implications for Empirical Research. *The Review of Economics and Statistics*, February 2003, 85(1): 226-234.

In particular, note that if one is calculating the Gini index of a sample for the purpose of estimating the value for a larger population, a small correction factor to the method used here may be needed for small samples.

HOW TO CITE

If you mention this model or the NetLogo software in a publication, we ask that you include the citations below.

For the model itself:

- Wilensky, U. (1998). NetLogo Wealth Distribution model. <http://ccl.northwestern.edu/netlogo/models/WealthDistribution>. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

Please cite the NetLogo software as:

- Wilensky, U. (1999). NetLogo. <http://ccl.northwestern.edu/netlogo/>. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

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