The Effects of Inequality on Global Economic Growth

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The Effects of Inequality on Global Economic Growth*

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Abstract

Previous efforts to determine the effect of inequality on growth, which relied on comparing growth rates of countries (or the same country over time) with different levels of inequality, have met with limited success. This paper provides a novel economic model that combines a Solow growth model with a closed 3-Equation model which includes the effects of inequality on consumer demand and thus growth. It models consumer demand using four income classes with different tax rates and propensities to consume whose sizes and incomes are determined by the level of inequality. It allows a wide range of inequality to be evaluated. This quantifies the effect of inequality on growth, but it also reveals its effects on interest rates and government spending guiding fiscal and monetary policy.

Among the unprecedented findings are 1) The maximum GDP growth occurs at a Gini coefficient of about 0.66 unless negative nominal interest rates or ongoing deficit spending is allowed; 2) Gini coefficients above 0.66 result in drastically reduced GDP caused by insufficient demand; 3) Below this point, there is excess demand which causes upward pressure on inflation and results in higher nominal interest rates; 4) At the current global Gini coefficient of about 0.62, real interest rates are near zero; 5) As inequality grows, the middle and upper middle classes shrink while the poor and rich classes expand.

Keywords: economic growth, inequality, interest rates, inflation

JEL classifications: D63, O40, E52, E62

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1. Introduction

Most analyses on the effect of income inequality on economic growth attempt to analyze an individual country's economic growth based on changes in its Gini coefficient over time, or compare different countries with different Gini coefficients. The results show small effects that are either positive or negative. The International Monetary Fund provides a good overview (IMF, 2015). These analyses are made more difficult because the changes (or differences) in Gini coefficients are small, and the effects are confounded by trade and financial capital flows.

The analysis in this paper started with the idea to develop an economic growth model that included the effects of inequality. Using a typical economic growth model is problematic because most growth models only consider the supply side. These models cannot accommodate the effects of different Gini coefficients. A different approach was needed. To overcome these difficulties, a closed global growth model is developed that also considers the demand side and central bank behavior. A Solow growth model is used to determine the potential output (supply) of the economy, and a 3-Equation model provides the demand side and central bank behavior. The potential output is subject to the demand limits of the demand side model. The demand side model uses agents for four income classes with different tax rates and propensities to consume. To avoid the effects of international trade and capital flows a closed global model is used. This implies an assumption that the global economy is sufficiently integrated to behave as a single economy. There are reasons to believe this assumption. Global trade has increased from 9% of global GDP in 1970 to about 25% today (Our World in Data, 2018), and in recent years interest rates and inflation seem to move more in unison. To allow a wide range of inequality to be analyzed, stylized Lorenz curves are used based on Gini coefficients. These curves produce income distributions that match data well. These curves are developed for Gini coefficients from 0.100 to 0.900. Thus, the model presented projects growth for a wide range of Gini coefficients.

The basic idea of the demand side model is that the poor and rich have different tax rates and propensities to consume. The rich are assumed to be taxed at a higher rate and have a lower propensity to consume than the poor with the middle class and upper middle class in between. When income inequality changes, these differences cause changes in demand. When demand is less than supply it constrains growth. When demand is more than supply it can overheat the economy and result in higher inflation. The central bank responds to these effects by lowering or raising interest rates. This affects output by changing consumer consumption and business investment. A model was needed that includes all of these effects. Fortunately, a simple model that meets this requirement exists, though it needs some modifications.

The model is the so-called 3-Equation model (Carlin and Soskice, 2015). It is a simple model that includes taxes and government spending, but also, importantly, it includes consumption, investment, inflation, and central bank behavior. The first equation relates output to interest rates. The second equation relates the difference between the potential output and the actual output to inflation. The third equation is a monetary rule to guide central bank interest rate changes based on an inflation target. The modifications include using a Solow growth model (Acemoglu, 2009) to provide a continuously changing potential output. The Solow model affects the 3-Equation model, but the 3-Equation model also affects the Solow model. For example, higher interest rates reduce investment and the potential output. Changes to the consumption model are also required. To capture the effect of different income distributions, consumption is divided among 4 agents (representing the poor, middle class, upper middle class, and the rich). While these classes are somewhat arbitrary, they are clearly defined. The poor have incomes that are less than ½ the median income; middle-class incomes are from ½ to 2 times the median income; upper-middle-class incomes are from 2 to 5 times the median income, and the rich have incomes greater than 5 times the median income. All of the information about income classes is derived from the stylized Lorenz curves, which can be differentiated to determine income distributions. With this information plus the total income and population of the economy, the size of each income class and the total income, taxes, and consumption of each class can be determined. The other change to the consumption model is the addition of an interest rate sensitivity similar to the investment model. Not all levels of inequality have all classes. Very low Gini coefficients have only the middle class. As the Gini coefficient increases, the middle class, and upper middle class shrink, while the poor and rich classes grow. The details of these modifications are shown in the Detailed Equations section.

A model like this requires significant calibration to real-world data. There are a few different types of calibration required. Some variables, like GDP, just need a starting point and are then projected within the model (endogenous). Some are within the model but their behavior is based on historical data, like consumption, investment, and total factor productivity. Others, like population, percent of the population employed, and human capital, are outside the model (exogenous) but are projected based on historical data and trends. One variable, the Gini coefficient, is completely exogenous and can be anything between 0.100 and 0.900. Government spending is assumed to match tax revenues unless deficit spending is allowed. Tax rates are based on historical tax revenue generation data. All of these calibrations are shown in Appendix A. An Excel implementation of the model is available for free online (Greaves, 2022). Instructions for the Excel model are shown in Appendix B.

This model can then be used to explore the effects of different Gini coefficients. In general, higher Gini coefficients result in lower demand and higher taxes. For high Gini coefficients, the nominal interest rate goes to zero in an attempt to stimulate demand. For these cases, the nominal interest rate cannot go much below zero because people will simply keep cash, so the economy cannot reach its potential without fiscal stimulus. This will probably need to be assisted by quantitative easing (or just "printing" money). It is hard to see how this can be maintained long-term. In history, this behavior has not ended well. The urge to print more money is irresistible, so too much money is printed resulting in hyperinflation. Short-term fiscal stimulus works without quantitative easing. However, the stimulus would have to be ongoing. If the government borrows by issuing bonds, these will eventually need to be repaid which would slow the economy. In any case, the model can be adjusted to allow negative nominal interest rates and estimate the level of fiscal stimulus needed for the economy to reach its full potential. Of course, reducing inequality could get us out of this trap. These outcomes are discussed in the Results section.

This Discussion section addresses how to interpret the results, how well this model represents our world today and an assessment of the strengths and weaknesses of the approach used in this paper.

Finally, the conclusions are presented in the Conclusions section.

2. Detailed Equations

The model has three parts that are well integrated. The equations are presented in three subsections (Solow growth model, 3-Equation model, and Lorenz Curves). Where appropriate, the value for each constant is shown. The origin of the constants is shown in Appendix A. For those who would like to dig deeply into the way the Excel workbook works, the row number in the Calc tab of each equation is shown in parentheses. As each equation is presented, only new variables are defined.

2.1 Solow Growth Model.

The potential global output (GDP) is the output the economy is capable of supplying and is projected using a modified Solow model. The model uses the number of employed individuals is used instead of the population. Human capital is added to the equation along with its additional exponent. The method of projecting capital is based on the previous year's capital plus investment calculated from the previous year's GDP minus depreciation and an interest rate effect. The total factor productivity is calculated based on the previous year's potential GDP. Some variables are defined by an equation of constants.

$Y_{g\,t} = K_t^{\gamma} H_t^{\beta} (L_{e\,t} A_t)^{(1-\gamma-\beta)}$, where (4) Eq. 1

$Y_{g\,t}$ = Potential global output for the current year, trillion 2011\$

K_t = Global capital stock for the current year, trillion 2011\$ (Godley, Lavoire, 2012)

$K_t = K_{t-1} + (I_d - \delta K_{t-1})$, where (14) Eq. 2

δ= Constant rate of depreciation, 0.0337

I_d = Gross investment for the current year, trillion 2011$ per year

$I_d = a_0 - 0.552\, r_{t-1}\, y_{t-1}$, where (61) Eq. 3

a_0 = The constant rate of investment as based on the previous year's output

$a_0 = 0.226\, y_{t-1}$ (51) Eq. 4

r_{t-1} = The previous year's real interest rate calculated using Eq. 10

y_{t-1} = Global gross output for the previous year -1, trillion 2011$/year (see Eq. 10) (13)

γ = The output elasticity of the capital stock, 0.36

H_t = The global index of human capital per person for the current year (78)

$H_t = 3.71 / (1 + e^{-0.019\,(t - 1980)})$ (24) Eq. 5

β = The output elasticity of the human capital stock, 0.26

$L_{e\,t}$ = The global number of persons employed for the current year, billions

$L_{e\,t} = L_t\, E_f$, where (19) Eq. 6

L_t = World population for the current year, billions

$L_t = 12.97 / (1 + e^{-0.0204\,(t - 2005)})$ (15) Eq. 7

E_f = Fraction of population employed for the current year

$E_f = 0.520 / (1 + e^{-0.020\,(t - 1919)})$ (20) Eq. 8

A_t = The total factor productivity for the current year

$A_t = 0.7457\, Y_{g\,t-1} + 0.4454$ (7) Eq. 9

2.2 The 3-Equation Model.

This model consists of the IS (Investment Savings), the PC (Phillips Curve), and the MR (Monetary Rule) equations. It is used by solving the PC and MR equations simultaneously for the global gross output in the next period. This output is then put into the IS equation to determine the previous period's required interest rate.

$y_t = A - a\, r_{t-1}$, IS equation, where (46) Eq. 10

$A \equiv k\,(c_0 + a_0 + G_t)$, where (48) Eq. 11

k = The multiplier

$k = \frac{1}{1-c_1(1-t)}$, where (49) Eq. 12

c_1 = The marginal propensity to consume

t = The tax rate

The marginal propensity to consume and the tax are calculated together as shown below.

$c_1\,(1\text{-}t) = c_{1p}\, f_{ip}\,(1\text{-}t_p) + c_{1m}\, f_{im}\,(1\text{-}t_m) + c_{1u}\, f_{iu}\,(1\text{-}t_u) + c_{1r}\, f_{ir}\,(1\text{-}t_r)$,

where (103) Eq. 13

c_{1p} = Marginal propensity to consume for the poor, 0.92

c_{1m} = Marginal propensity to consume for the middle class, 0.89

c_{1u} = Marginal propensity to consume for the upper middle class, 0.76

c_{1r} = Marginal propensity to consume for the rich, 0.64

t_p = Tax rate for the poor, 0.03

t_m = Tax rate for the middle class, 0.11

t_u = Tax rate for the upper middle class, 0.17

t_r = Tax rate for the rich, 0.23

The f_{ip}, f_{im}, $f_{iu,}$ and f_{ir} terms are the fractions of total income that go to the four classes and are further explained in the Lorenz curves subsection.

c_0 = The constant or autonomous consumption as a fraction of the previous year's output, trillions of 2011$

$c_0 = (c_{0p}\, f_{ip} + c_{0m}\, f_{im} + c_{0u}\, f_{iu} + c_{0r}\, f_{ir})\, y_{t-1}$, where (102) Eq. 14

$c_{0p}\, f_{ip}$ = poor autonomous consumption

$c_{0m}\, f_{im}$ = middle class autonomous consumption

$c_{0u}\, f_{iu}$ = upper middle-class autonomous consumption

$c_{0r}\, f_{ir}$ = rich autonomous consumption

For this analysis, autonomous consumption for all classes is zero.

$G_t = (t_p\, f_{ip} + t_m\, f_{im} + t_u\, f_{iu} + t_r\, f_{ir})\, y_{t-1}$, where (56) Eq. 15

G_t = Government spending at year t. It is equal to the tax revenues. Deficit spending to reach the economic potential is also calculated, trillions of 2011$

$G_{dt} = (Y_{g\,t} - y_t + G_{dt-1}) / k$, where (59) Eq. 16

G_{dt} = Deficit spending, when allowed, at year t, 2011$

$a \equiv k\,(a_1 + c_2)$, where (49) Eq. 17

a_1 = Interest rate coefficient for investment, 0.552

c_2 = Interest rate coefficient for consumption, 0.779

$\pi_t = \pi_{t-1} + \alpha\,(y_t - Y_{g\,t})$, PC equation where (37) Eq. 18

π_t = Inflation for the current year

π_{t-1} = Inflation for previous year

α = Output/inflation coefficient, 0.500

$(y_t - Y_{g\,t}) = -\alpha\,\beta\,(\pi_t - \pi^T)$, MR equation where (42) Eq. 19

β = Relative weight of inflation versus unemployment, 0.500

π^T = Target value for inflation, 2%

2.3 Lorenz Curves.

Stylized Lorenz curves are created using an exponential curve form. This equation is then differentiated to obtain an income distribution. From that, the median income is determined. Once this is known, the percentage of the population in each of the four income categories (poor, middle class, upper middle class, and rich) are determined. Using the Lorenz curve, the percentage of income going to each income class is determined. Finally, total consumption and tax revenues can be determined.

$i_c = a_l\, e^{b_l\, P_c} - \ a_l$, Lorenz curve, where (85-88) Eq. 20

i_c = Cumulative share of income

a_l = Base constant

e = The natural number, 2.71828

b_l = Exponent constant

The constants are chosen to ensure the curve passes through 0,0 and 1,1 and has the desired Gini coefficient. The values of the coefficients for selected Gini coefficients are shown in Table 1. The Excel file has all the 3-digit Gini coefficient values from 0.100 to 0.900 along with the associated a_l and b_l constants.

Table 1 Lorenz curve coefficients for selected Gini coefficients

Gini Coefficient	a_l	b_l
0.10	1.207E+00	0.603
0.20	4.169E-01	1.223
0.30	1.761E-01	1.899
0.40	7.491E-02	2.664
0.50	2.859E-02	3.583
0.60	8.417E-03	4.786
0.62 Current actual	3.870E-03	5.558
0.70	1.386E-03	6.583
0.80	4.826E-05	9.939
0.90	2.074E-09	19.994

P_c = Cumulative share of the population

$i_s = a_l\, b_l\, e^{bl\, P_c}$, Income curve, where (75) Eq. 21

i_s = Individual share of income at P_c

$i_m = i_s\, y_{t-1} / P_t$, where $P_c = 0.5$ (75) Eq. 22

i_m = Median per capita income

P_t = Population at the current year

Median per capita incomes of the income classes for selected Gini coefficients are shown in Table 2.

Table 2 Median per capita incomes of the incomes for selected Gini coefficients

Gini coefficient	Median per capita income, $
0.10	10,017
0.20	9,746
0.30	8,796
0.40	7,694
0.50	6,254
0.60	4,488
0.70	2,496
0.80	703
0.90	9

$P_c = Ln\left(\frac{i_s P_t}{a_l\, b_l\, y_{t-1}}\right)/b_l$, where $0 < P_t < 1$ (76,77,78) Eq. 23

This combines equations for the median per capita income and the individual share of income above and solves for the cumulative share of the population with income less than or equal to an income level. It is used to calculate the cumulative share of the population with income of $< 0.5\ i_m$, $<2.0\ i_m$, and $<5.0\ i_m$. The remainder has incomes $> 5.0\ i_m$. These values are used to calculate the shares of the population that are poor, middle class, upper middle class, and rich. The percent of the population that is poor, middle class, upper middle class, and rich for selected Gini coefficients is shown in Table 3.

Table 3 Percent of the population by income class for selected Gini coefficients

Gini Coefficient	% Poor	% Middle Class	% Upper Middle Class	% Rich
0.10	0.0	100.0	0.0	0.0
0.20	0.0	100.0	0.0	0.0
0.30	13.5	73.0	13.5	0.0
0.40	24.0	52.0	24.0	0.0
0.50	30.7	38.7	25.6	5.1
0.60	35.5	29.0	19.1	16.4
0.62 Current actual	37.5	24.9	16.5	21.0
0.70	39.5	21.1	13.9	25.6
0.80	43.0	13.9	9.2	33.8
0.90	46.5	6.9	4.6	42.0

$F_p = P_c\ (0.5\ i_m)$ Eq. 24

F_p = Fraction of the population that is poor

$fm = P_c\ (2.0\ i_m) - P_c\ (0.5\ i_m)$ Eq. 25

fm = Fraction of the population that is middle class

$f_u = P_c\ (5.0\ i_m) - P_c\ (2.0\ i_m)$ Eq. 26

f_u = Fraction of the population that is upper middle class

$f_r = 1 - P_c\ (5.0\ i_m)$ Eq. 27

f_r = Fraction of the population that is rich

Finally, the shares of the total income that goes to each income class can be determined.

$$f_{ip} = a_l\, e^{b_l\, f_p} - \; a_l, \text{ where} \quad \text{Eq. 2}$$

f_{ip} = Share of total income that goes to the poor

$$f_{im} = a_l\, e^{b_l\, (f_p\, +\, f_m)} - \; a_l - f_{ip}, \text{ where} \quad \text{Eq. 29}$$

f_{im} = Share of total income that goes to the middle class

$$f_{iu} = a_l\, e^{b_l\, (f_p\, +\, f_m\, +\, f_u)} - \; a_l - f_{ip} \; - f_{im}, \text{ where} \quad \text{Eq. 30}$$

f_{iu} = Share of total income that goes to the upper middle class

$$f_{ir} = 1 - \; f_{ip} - f_{im} - f_{iu}, \text{ where} \quad \text{Eq. 31}$$

f_{ip} = Share of total income that goes to the rich

The values of the income shares of each class for selected Gini coefficients are shown in Table 4.

Table 4 Values of the income shares of each class for selected Gini coefficients

Gini Coefficient	% Income to Poor	% Income to Middle Class	% Income to Upper Middle Class	% Income to Rich
0.10	0.0	100.0	0.0	0.0
0.20	0.0	100.0	0.0	0.0
0.30	5.1	68.3	26.6	0.0
0.40	6.7	42.6	50.7	0.0
0.50	5.7	25.7	51.4	17.1
0.60	3.8	13.8	27.6	54.8
0.62 Current actual	2.7	9.3	18.7	69.2
0.70	1.7	5.6	11.2	81.5
0.80	0.3	1.0	2.1	96.5
0.90	0.0	0.0	0.0	100.0

3. Results

The results of this study are straightforward, even intuitive in hindsight, but have far-reaching implications. In this section, the results are provided in a few simple graphs. Each graph has three lines labeled Interest>0 (the nominal interest rate must be greater than 0), Deficit Spending (deficit spending to use excess supply is allowed), and Interest>-1 (the nominal interest rate may be negative).

3.1 World GDP

Fig. 1 shows that there is a Gini coefficient that provides a maximum economic growth rate at a Gini coefficient of about 0.66. It does this by comparing the projected global GDP in 2050 with the 2019 global GDP. For Gini coefficients below the maximum growth point, the growth drops off slowly.

However, above that point, it drops off dramatically. For a Gini coefficient of 0.90, GDP drops by 77% between 2019 and 2050. The reason for this dramatic drop-off is at higher Gini coefficients, demand drops. As demand drops, nominal interest rates are lowered to maintain demand. Once nominal interest rates reach zero, demand can only be supported by perpetual deficit spending and quantitative easing, or allowing the nominal interest rate to go negative.

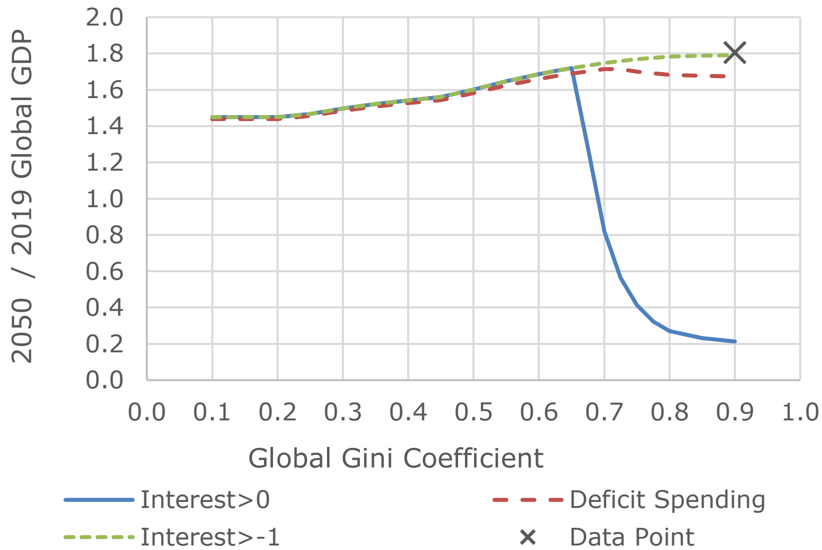

Fig. 1 GDP versus Gini coefficient

3.2 Interest Rates

Fig. 2 shows the stabilized nominal interest rate compared to the Gini coefficient. The nominal interest rate stabilizes relatively quickly with a constant Gini coefficient. The nominal interest rate in 2050 is shown. It reaches zero at a Gini coefficient of about 0.66. Beyond that point, the minimum nominal interest rate is either held at zero, held at zero with deficit spending, or allowed to go negative. Holding the nominal interest rate positive results in a significant drop in GDP. The deficit spending as calculated can only delay the nominal interest rate from reaching zero to a Gini coefficient of about 0.8. If the nominal interest rate is allowed to go negative, it reaches a minimum value of -2.6% at a Gini coefficient of 0.90. None of the options above a Gini coefficient of 0.66 are attractive, but deficit spending appears to be the only viable option. The only attractive option is to keep the Gini coefficient below 0.66. Based on limited data from (Wikipedia contributors, "Gini coefficient") and (Our World in Data, “Global Economic Inequality”) the current global Gini coefficient is estimated to be about 0.62 and has been trending slightly downward. Of course, there is no guarantee that it will continue to go down. Another effect of passing the point where nominal interest rates need to go negative but are not allowed is negative inflation as discussed below. Given the uncertainty in the data and the assumptions used in this analysis, it seems we are close to the edge of the cliff. The graph also shows the point where the real interest rate and the inflation rate are both 2% with a nominal interest rate of 3.97% at a Gini coefficient of 0.53.

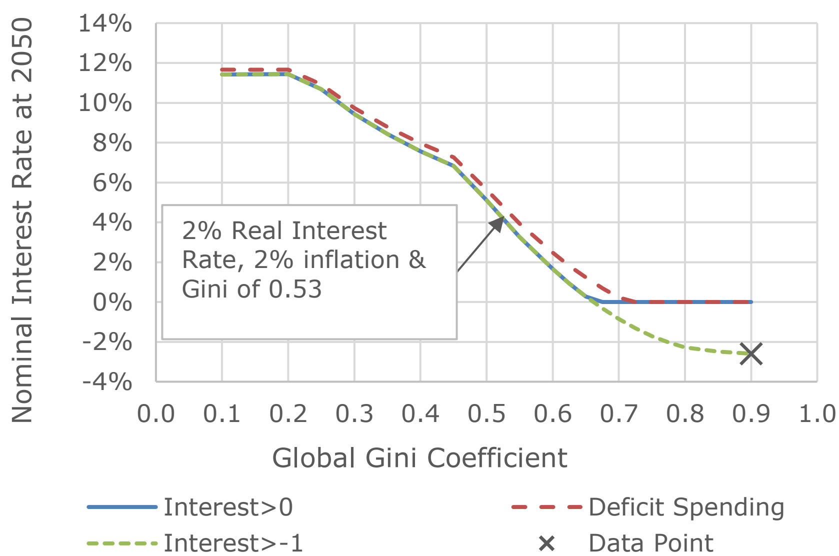

Fig. 2 Nominal interest rate versus Gini coefficient

3.3 Government Spending

The Gini coefficient also affects government revenues as shown in Fig. 3. Spending is assumed to equal tax revenues except when deficit spending is allowed. This also stabilizes relatively quickly. Government spending as a percent of GDP in 2050 used. Global government spending in 2019 is just under 20%. In the worst case with deficit spending, it increases to 29%.

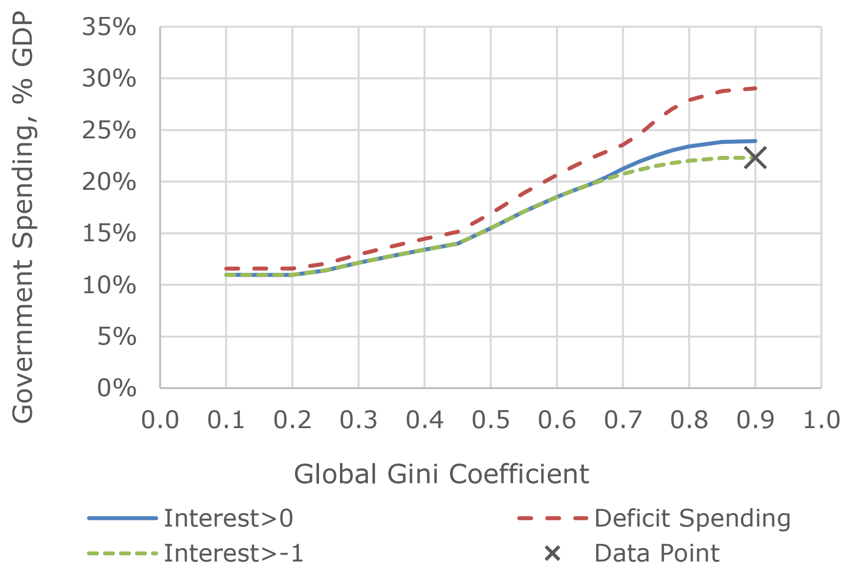

Fig. 3 2050 government spending versus Gini coefficient

3.4 Deficit Spending

Fig. 4 shows the level of deficit spending required to reach the economy's potential. The level of deficit spending is difficult to determine at the beginning of a year given only what is known at that point. The method chosen in this analysis attempts to do this but falls short when the Gini coefficient is above about 0.80. At that point, the nominal interest rate reaches the limit of zero, and negative inflation results.

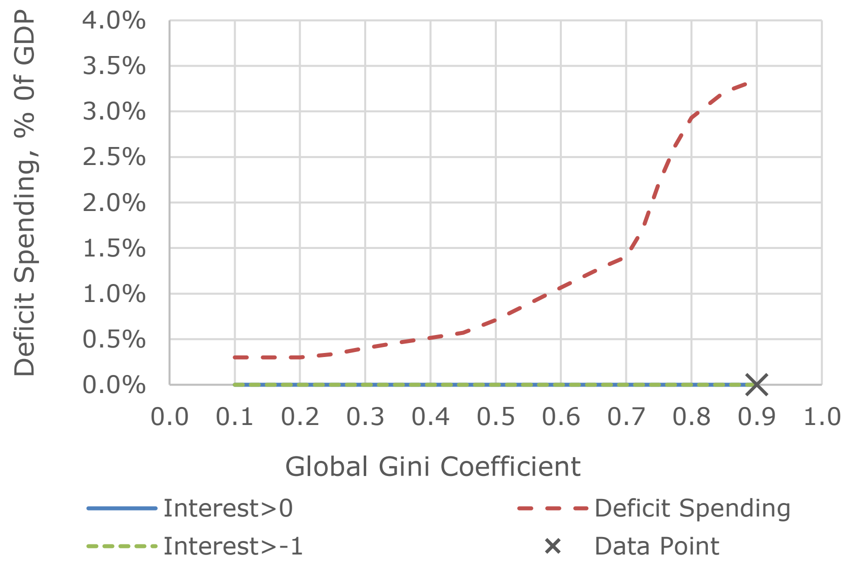

Fig. 4 2050 deficit spending versus Gini coefficient

3.5 Inflation

In this analysis, inflation is held at the target value of 2% by adjusting the interest rate to match supply and demand. This works perfectly until the nominal interest rate needs to go negative to reach the economy's full potential. If it is not allowed to go negative, inflation rapidly goes significantly negative above a Gini coefficient of about 0.66 as shown in Fig. 5. Basically, the economy quits working.

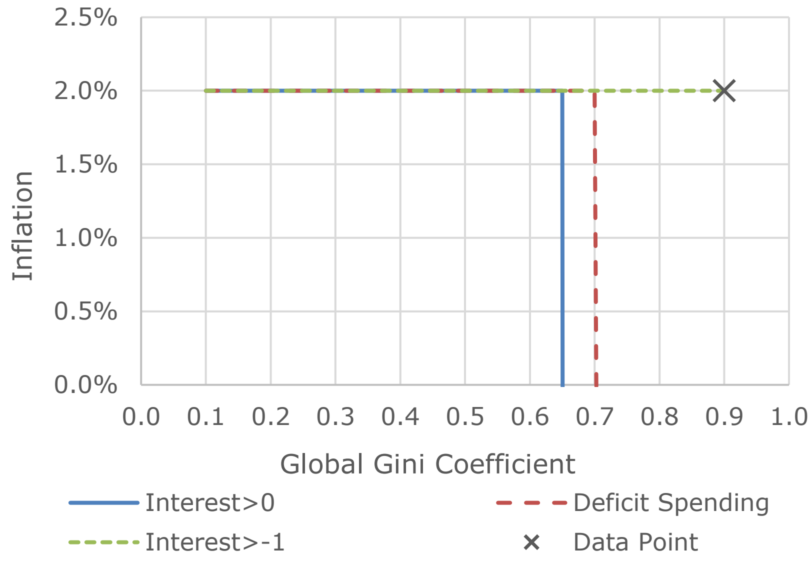

Fig. 5 2050 Inflation versus Gini coefficient

3.6 Consumption

The final result is consumption as shown in Fig. 6. If a goal is to maximize utility and utility can be approximated by consumption, then maximizing consumption would be an appropriate goal. This analysis shows that consumption is maximized at a Gini coefficient of 0.25. This is far below our current global Gini coefficient of 0.62. Only 2 countries have Gini coefficients lower than 0.25. Also, at that level, the model indicates that nominal interest rates would be above 10%. If an optimum goal for the Gini coefficient is desired, the best choice seems to be about 0.53. This provides desirable interest and inflation rates, with only a small reduction in consumption.

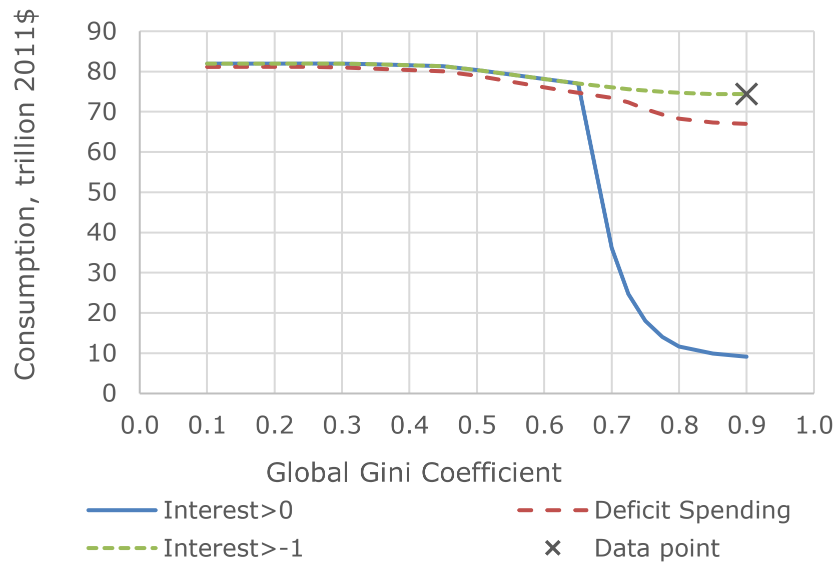

Fig. 6 2050 Consumption versus Gini coefficient

4. Discussion

For the model to represent our world, it was calibrated with global data as shown in Appendix A. However, there are several areas of concern. First, is the assumption that the global economy is sufficiently integrated to behave like a single closed economy. While it is true that there are many currencies in use and individual countries try to manage their economies, the global economy is much more integrated today than it was 50 years ago. Money can move around the world easily. Since 1970, global trade has almost tripled as a percent of global GDP. Complex supply chains source labor, materials, and intermediate products in the lowest-cost countries. While there may be a retreat from this practice caused by the Covid pandemic, it remains to be seen if this will last once the pandemic is behind us. Finally, the model does predict the low interest rates and inflation that we have transitioned to over the last couple of decades (before the Covid pandemic) as trade dramatically increased. While all this doesn't show that the world economy is a single closed economy, it does suggest that it may be starting to behave like one.

The next area of concern is the limited amount of global data in several areas related to economic inequality, and how income, taxes, and consumption are distributed among the various income classes. The most common measure of income inequality is the Gini coefficient, but historical estimates of global Gini coefficients are only available for a decade or so, and the quality of those is not great. It is often unclear whether they are based on market or disposable incomes although most recent ones use disposable income (although most recent ones use disposable income). Not all countries report Gini coefficients and of those that do, not all report it every year. On the plus side, Gini coefficients change very slowly. Aggregating Gini data from different countries is tricky. If the underlying distribution data is not available for individual countries, it can be estimated based on the country's GDP, population, and Gini coefficient to aggregate the data. The stylized Lorenz curves described in this paper can help in that effort. The 2020 global income distribution is estimated using the Gini coefficient, population, GDP, and the stylized Lorenz curves of the individual countries to estimate the income distributions of individual countries, (Wikipedia contributors, "List of countries by income equality"), (Wikipedia contributors, "List of countries and dependencies by population"), and (Wikipedia contributors, "List of countries by GDP (nominal)"). These are summed to give the global income distribution used to calculate the global Gini coefficient as shown in the **Global Gini Calc** tab of the Excel model. However, that analysis results in a global Gini coefficient of about 0.67 compared to about 0.62 from 2 other published estimates. It is not clear which is the better estimate. An indication that a global Gini coefficient of 0.62 may be correct is an estimate of the 2013 median global per capita income of $3,227/year based on a 2013 Gini coefficient of 0.65. This is close to an actual estimate of $2,920/year (Gallup, 2013). The calculated version uses country Gini coefficients for various years from 1992 to 2020 with an average of 2015. This makes it difficult to assign it to a specific year which may explain the difference. For the calculated approach to be useful, an adjustment may be needed to make them represent the same year. For this paper, a global Gini coefficient of about 0.62 was chosen to represent the current value.

The global marginal propensities to consume and tax rates of the various income classes are not well known. The values chosen are summarized in Table 5.

Table 5 Marginal propensity to consume and income tax rates for income classes

Income Class	Marginal Propensity to Consume	Tax Rate
Poor	0.92	0.03
Middle	0.89	0.11
Upper Middle	0.76	0.17
Rich	0.64	0.23

The combination of the global marginal propensities to consume and tax rates along with the Gini coefficients and GDP, defined for each income class, need to result in consumption and tax revenues that match the data for years where data is available. However, this is not sufficient to uniquely define the global marginal propensities to consume and tax rates. Some data indicate that the poor and middle class save very little and that the upper middle class and rich have much higher savings rates (Financial Samurai, 2022). This indicates the rich have lower propensities to consume than the poor. It seems obvious that the rich pay taxes at a higher rate than the poor since most tax laws are progressive (those with high incomes have higher tax rates than the poor), but tax laws are complex with many special provisions. The rich and upper middle classes have the resources to implement effective tax reduction strategies. Despite this, the rich are assumed to pay taxes at a higher rate than the poor. Even with these additional constraints, the global marginal propensities to consume and tax rates cannot be uniquely defined. The chosen values should be considered as a set of values that meet the constraints, but not the only set of values that meet the constraints.

The discussion above and the results in Appendix A show that this model is a reasonable representation of our world, but there is uncertainty that indicates the results should not be considered precise. However, the general behavior exhibited is probably representative of our world. This leads to the discussion of how to interpret the results.

The results should not be considered predictions. Aside from the imprecision of the model, many things could change the results. The Covid pandemic is an excellent example. Initially, governments provided aggressive fiscal spending to support the economy. At the same time, supply chains bogged down. As we started to learn how to live with the pandemic, demand picked up (especially for products since experiences like eating out were unavailable or unsafe). Shortages caused price increases leading to overall inflation. To bring inflation under control central banks have started raising interest rates. Another example is the control of interest rates and inflation. In the model interest rates are applied based on data from the previous year, there is a lag, and then inflation dutifully responds. In the real world, it is much messier. Knowing what the right decision is and making it are not straightforward. Even if central banks make the right decision, consumers and businesses may not respond as anticipated. So, the results should be interpreted as an underlying pressure pushing the economy toward these conditions.

5. Conclusions

There are three tools presented in this paper. First, by combining an economic growth model with a model that includes supply, demand, and central bank behavior, the effects of consumer demand on growth can be evaluated. The second is the use of stylized Lorenz curves to determine income distributions from Gini coefficients which allows a wide range of Gini coefficients to be explored. Finally, the stylized Lorenz curves also allow multiple types of consumers (in this case, poor, middle class, upper middle class, and rich) to be defined. The combination of these tools allows the effects of inequality on economic growth to be evaluated over a wide range of Gini coefficients. This also provides a mechanism of how interest rates and inflation interact with inequality and economic growth.

The following findings show that income distribution can have dramatic effects on interest rates, inflation, and economic growth.

1. 1) Unless negative nominal interest rates or ongoing deficit spending is allowed, the maximum GDP growth occurs at a Gini coefficient of about 0.66. GDP at 2050 drops from 1.74 times the 2019 GDP at a Gini coefficient of about 0.66 to about 0.23 times the 2019 GDP at a Gini coefficient of 0.90.
2. The drastic reduction above a Gini coefficient above 0.66 is caused by insufficient demand when the nominal interest rate falls to zero. Then growth must be supported by allowing negative nominal interest rates or continuous additional stimulus like deficit spending.
3. Below a Gini coefficient of about 0.66, there is excess demand which causes upward pressure on inflation and results in higher nominal interest rates. At a Gini coefficient of about 0.53, the result is a real interest rate of about 2%, a nominal interest rate of about 4%, and only a slightly lower growth rate.
4. At the current global Gini coefficient of 0.62, real interest rates must remain near zero. This is our world unless the global economy stops behaving as a single economy due to balkanization, some calamity (like a pandemic), or the global Gini coefficient drops significantly.
5. To maximize utility, maximum consumption is achieved at a Gini coefficient of about 0.26. However, the nominal interest rate at that level is above 10%.
6. As the Gini coefficient grows, the middle and upper middle classes shrink while the poor and rich classes expand

All of this suggests that a Gini coefficient of about 0.53 may be a worthy goal.

Future work to better define global Gini coefficients and the taxes and propensities to consume of various income classes would consolidate our understanding of the interaction of inequality and economic growth. Beyond that, the interaction between inequality and climate change needs to be investigated (Greaves, 2020) and (Greaves 2021).

6. Acknowledgments

First of all, I would like to thank my wife, Lisa, for always encouraging me and indulging my time holed up in my office. I would also like to thank Daron Acemoglu, and Wendy Carlin and David Soskice for their enlightening books. Though I never communicated with them, their thinking came out loud and clear in their books.

Appendix

Appendix A: Calibration

For a model to exhibit realistic behavior it must be calibrated to the real world. Unfortunately, there is not enough data available to precisely calibrate the model. However, there is enough data to calibrate the model well enough to exhibit realistic behavior. This section is divided into several subsections where individual areas are calibrated.

A.1 Global Population

The future global population is estimated using a logistic curve fit to the historical data and the United Nations projections as shown in Fig. 7.

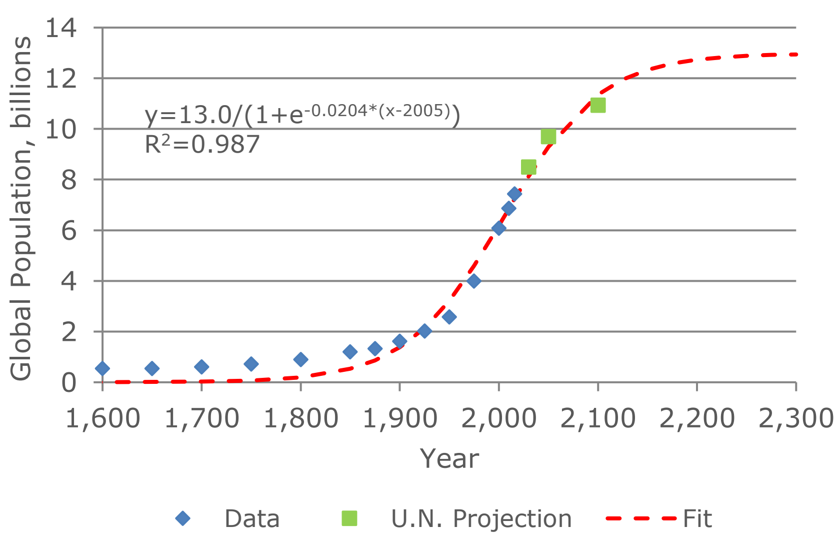

Fig. 7 Global population projection[a]

a. Data from (Wikipedia contributors, World Population) and (United Nations, 2019).

A.2 Human Capital

The available data for the US and global per capita human capital is from 1952 to 2014. US human capital is the world's highest per capita and appears to be approaching a maximum. Logistic curve fits are used for both the US and global data. The fit for the world assumes that it will approach the same maximum as the US as shown in Fig. 8.

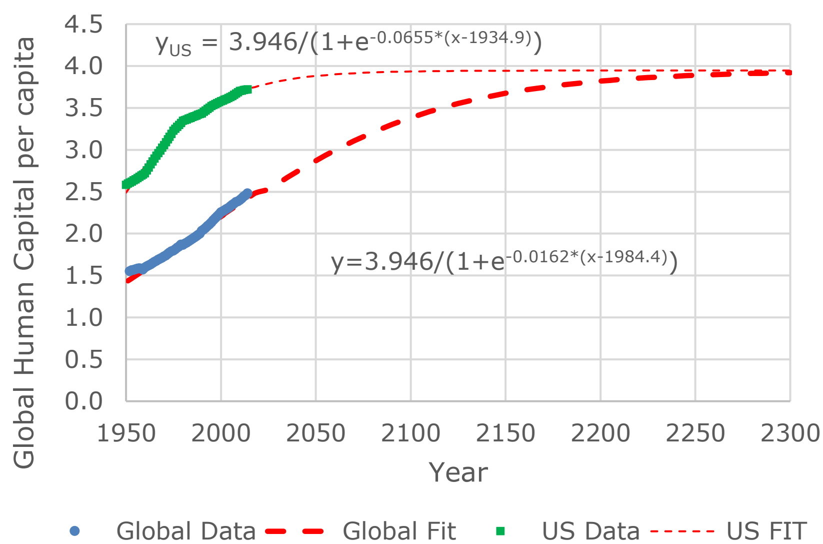

Fig. 8 Human capital projection[b]

b. Data was compiled from (Feenstra, 2015).

A.3 Global Percent of Population Employed

A logistic curve fit of the 1952 to 2014 data is used to project the global percent of the population employed as shown in Fig. 9. This is used with the population to determine the number of employed individuals.

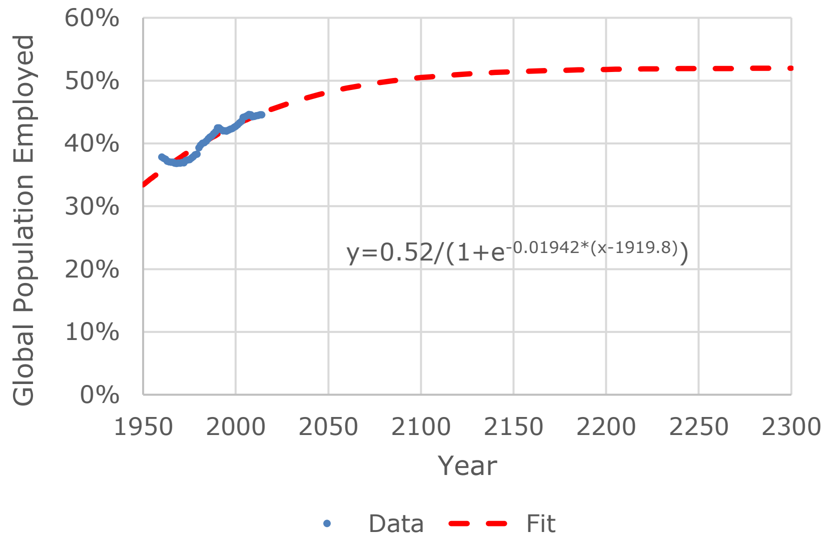

Fig. 9 Percent of the global population employed projection [c]

c. Data was compiled from (Feenstra, 2015).

A.4 Calculated versus Actual Global Tax Revenues

The calculated global revenues are based on Eq. 15 and the constants described in the Detailed Equations section. A linear curve fit shows a good correlation between the calculated and actual revenues as shown in Fig. 10.

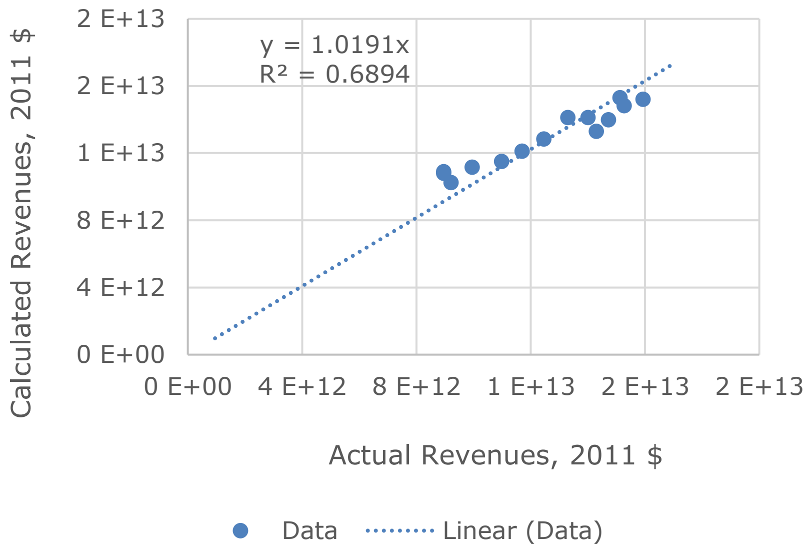

Fig. 10 Calculated versus actual global tax revenues [d]

d. Data from (OECD, 2022)

A.5 Consumption

The calculated total consumptions are based on the equations and constants described in the Detailed Equations section. To calibrate the propensities to consume of the various income classes, total consumption is calculated by Eq. 32 and is shown in Fig. 11.

$C_t = GDP_{t-1}\ (c_0 + c_1\ (1\text{-}t) - C_2\ r_{t-1})$, where (65) Eq. 32

C_t = Total consumption.

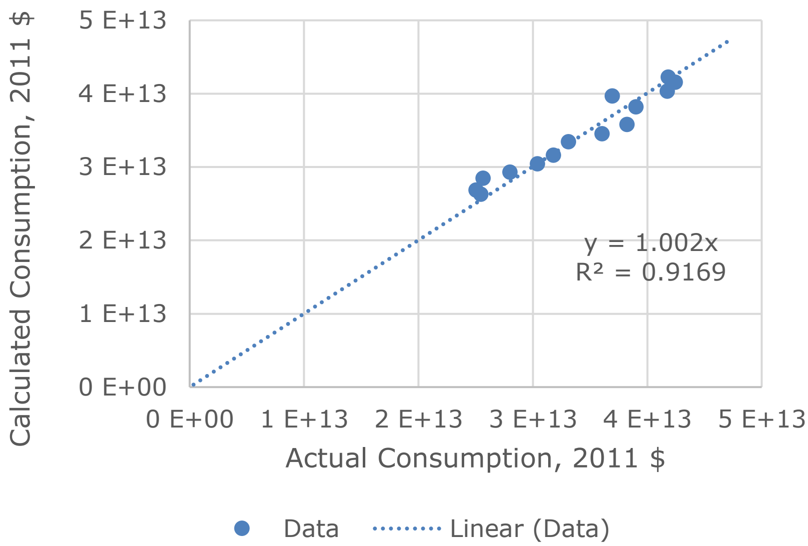

Fig. 11 Calculated versus actual global consumption[e]

e. Data is from (The World Bank, 2021)

A.6 Total Factor Productivity

The total factor productivities for the years 1952 to 2014 are calculated based on Eq. 1 and the constants described in the Detailed Equations section. Future Total Factor Productivities are estimated based on the curve fit of the data using the previous year's global GDP as shown in Fig. 12.

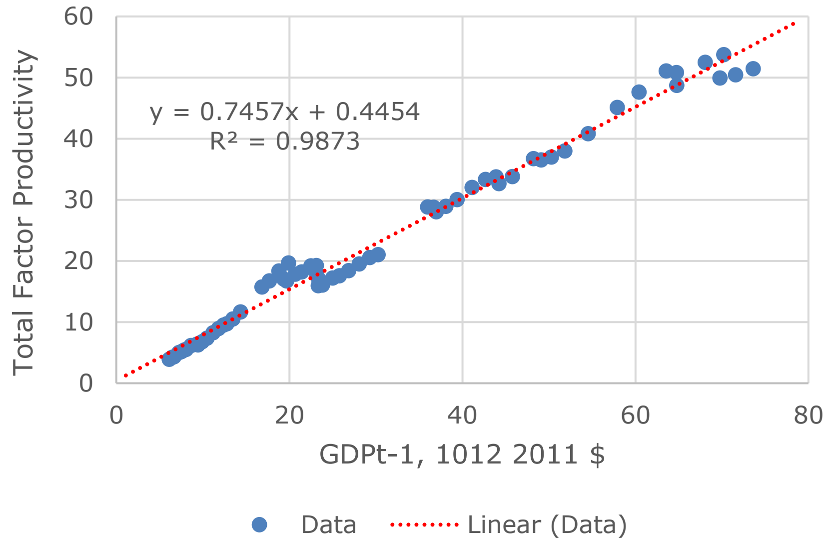

Fig. 12 Previous year global GDP versus calculated actual global total factor productivity

A.7 Global Investment

The calculated investments are based on Eq. 3 and the constants described in the Detailed Equations section. These are compared to actual investments in Fig. 13.

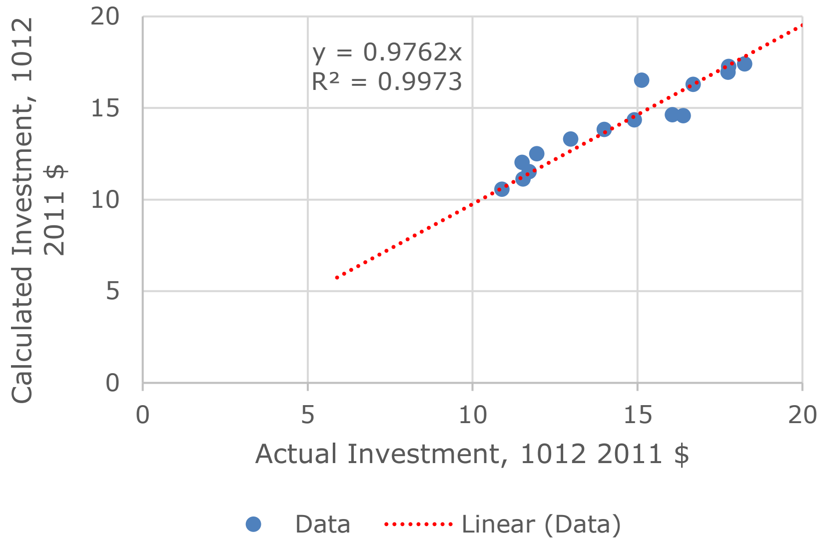

Fig 13 Calculated versus actual global investment[f]

f. Actual values from (International Monetary Fund. 2021). Choose, "TAB DELIMITED VALUES: By Country Groups" to get world numbers.

A.8 Stylized Lorenz Curves

As an example, the stylized Lorenz curve for the 2020 US income distribution was derived from the income distribution data. Using that data, a Gini coefficient was calculated. Finally, the stylized Lorenz curve was created from the calculated Gini coefficient (Gini= 0.457, a_l= 0.04418, b_l= 3.163). The excellent fit is apparent in Fig. 14. The analysis to estimate the global Gini coefficient, as described in the Discussion section, also generated an income distribution and a Gini fit. This also resulted in an excellent fit as shown in Fig. 15.

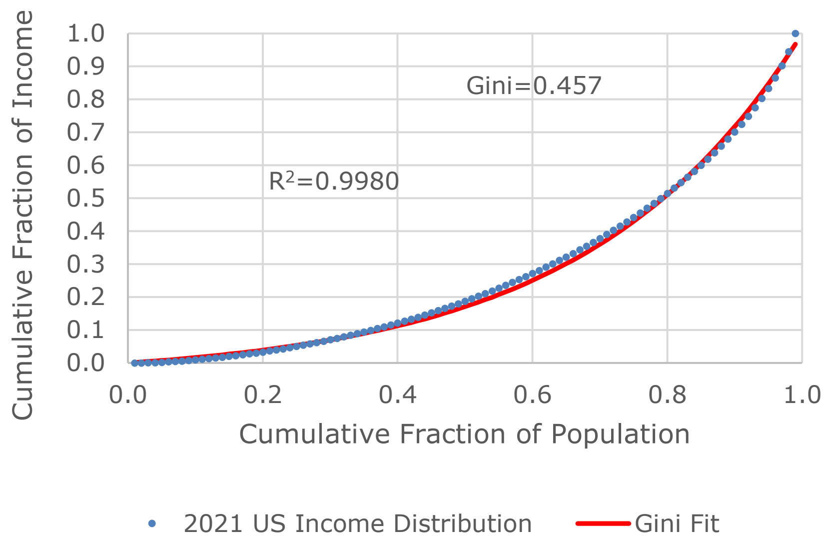

Fig. 14 US income distribution[g]

g. Actual from (DQYDJ. 2022)

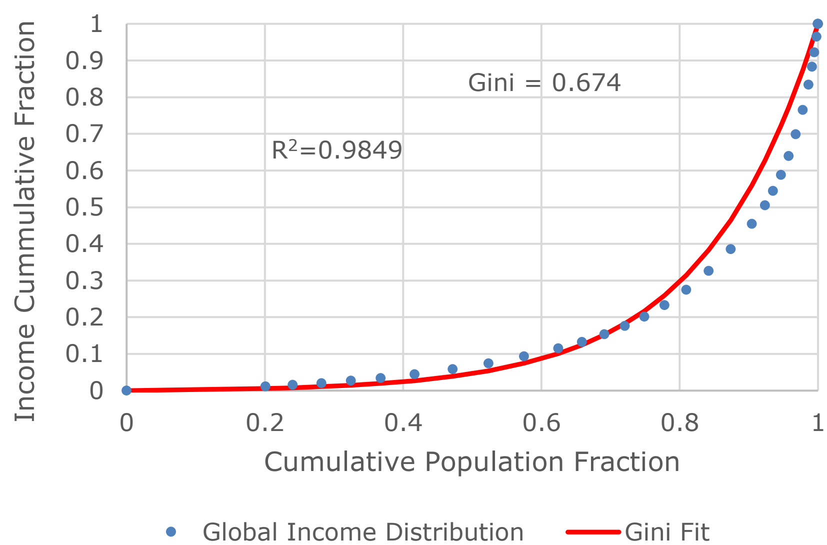

Fig. 15 Global income distribution

Appendix B. Instructions for Gini Excel workbook Gini V1.0.xlsm

The model described in this paper is implemented in the Gini V1.0 Excel workbook Gini V1.0.xlsm. The workbook is easy to use. There are 8 tabs. If the graphs need to be updated, there is a macro to do it. Of course, macros must be enabled. The workbook is not password protected, so there is access to the entire workbook including the macro. These instructions are organized by tabs.

The **Help** tab contains a copy of these instructions.

On the **Main** tab, graphs show the values of key outputs for the whole range of Gini coefficients from 0.100 to 0.900. Each graph has an "X" that shows an individual point which can be chosen for any point on the graphs. The values of that point on all the graphs are shown in a table (B11:C17). A point can be chosen by changing the values in cells C4, C6, and C8. These parameters also set the conditions for the graphs on the Time Graphs tabs. The graphs show values for the year 2050. The year can be any integer between 2020 and 2300 in cell C11. If the year is changed, the graphs must be updated. This is done by clicking the Update Graphs button in cell B9. It takes about 2 or 3 minutes to run.

The **Time Graphs** tab shows how a few key variables vary with time. The conditions for the graphs are controlled on the Main tab cells C4, C6, and C8.

The **Parameters** tab lists many of the constants used in the calculation. Any of these can be changed if better information becomes available. If the value of any parameter is changed the graphs must be updated by clicking the Update Graphs button on the Main tab.

The **Calc** tab contains all of the calculations.

The **Gini a b** tab contains all of the base and exponent constants used to calculate the Lorenz curves based on the Gini coefficients.

The **3 Eq. Graphs** tab is used by the macro to compile the data for all the graphs on the main tab.

The **Exo Graphs** tab contains the data and graphs used in calibration.

Finally, the **Global Gini Calc** tab contains three estimates of the 2019 Gini coefficient.

References

Acemoglu, Daron. 2009. *Introduction to Modern Economic Growth*. Princeton, New Jersey, and Oxford, England: Princeton University Press.

Carlin, Wendy, and David Soskice. 2015. *Macroeconomics, Institutions, Instability and the Financial System*. Oxford, England: Oxford University Press.

DQYDJ, 2022, "Average, Median, Top 1%, and all United States Household Income Percentiles" https://dqydj.com/average-median-top-household-income-percentiles/ (accessed July 27, 2022).

Feenstra, Robert C., Robert Inklaar and Marcel P. Timmer, 2015, "The Next Generation of the Penn World Table", American Economic Review, 105(10), 3150-3182, www.ggdc.net/pwt (accessed July 27, 2022).

FinancialSamurai, 2022, "The Average Saving Rate By Income (Wealth Class)", https://www.financialsamurai.com/the-average-savings-rates-by-income-wealth-class/ (accessed July 27, 2022).

Gallup, 2013, "Worldwide, Median Household Income About $10,000" https://news.gallup.com/poll/166211/worldwide-median-household-income-000.aspx (accessed July 27, 2022).

Greaves, Gerry. 2020. *Crazy Climate and Rigged Economies, We Can Do Much Better*. Pittsburg, Pennsylvania: Dorrance Publishing.

Greaves, Gerry, 2021, "Assessing the Uncertainty in Integrated Climate Economy Models (Working Paper)", https://sites.google.com/view/crazyclimatebook/home/blog (accessed July 27, 2022).

Greaves, Gerry, 2022, "Gini Excel workbook". https://sites.google.com/view/crazyclimatebook/home/information (accessed July 27, 2022).

Godley, Wynne, and Marc Lavoire. 2012. *Monetary Economics, An Integrated Approach to Credit, Money, Income, Production, and Wealth*. New York, New York: Palgrave Macmillan.

International Monetary Fund, 2015, "Causes and Consequences of Income Inequality: A Global Perspective", https://www.imf.org/external/pubs/ft/sdn/2015/sdn1513.pdf (accessed July 27, 2022).

International Monetary Fund, 2021, "World Economic Outlook Database", https://www.imf.org/en/Publications/WEO/weo-database/2021/October/download-entire-database (accessed July 27, 2022).

Organization for Economic Co-operation and Development, 2022, "Global Revenue Statistics Database", https://stats.oecd.org/Index.aspx?DataSetCode=RS_GBL (accessed July 27, 2022).

Our World in Data, 2018, "Trade and Globalization", https://ourworldindata.org/trade-and-globalization (accessed July 27, 2022).

Our World in Data, n.d., “Global Economic Inequality”, https://ourworldindata.org/global-economic-inequality (accessed July 27, 2022).

The World Bank, 2021, “Households and NPISHs Final consumption expenditure”, https://data.worldbank.org/indicator/NE.CON.PRVT.CD (accessed July 27, 2022).

United Nations, 2019, “World Population Prospects 2019 Highlights”, https://population.un.org/wpp/Publications/Files/WPP2019_Highlights.pdf (accessed July 27, 2022).

Wikipedia contributors, n.d., "Gini coefficient," Wikipedia, The Free Encyclopedia, https://en.wikipedia.org/wiki/Gini_coefficient (accessed July 30, 2022).

Wikipedia contributors, n.d., "List of countries and dependencies by population," Wikipedia, The Free Encyclopedia, https://en.wikipedia.org/wiki/List_of_countries_and_dependencies_by_population (accessed July 30, 2022).

Wikipedia contributors, n.d., "List of countries by GDP (nominal)," Wikipedia, The Free Encyclopedia, https://en.wikipedia.org/wiki/List_of_countries_by_GDP_(nominal) (accessed July 30, 2022).

Wikipedia contributors, n.d., "List of countries by income equality," Wikipedia, The Free Encyclopedia, https://en.wikipedia.org/wiki/List_of_countries_by_income_equality (accessed July 30, 2022).

Wikipedia contributors, n.d., "World Population," Wikipedia, The Free Encyclopedia, https://en.wikipedia.org/wiki/World_population (accessed July 30, 2022).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- GiniV1.0.xlsx