The inescapable structure of economic inequality: K with r and Y with g, where r > g

Lee, Sangdon

22 July 2024

The inescapable structure of economic inequality:

K with r and Y with g, where r > g

Corresponding author: Sangdon Lee, Ph.D.,

4156 Morningdale Dr., Troy, MI. 48085, USA.

ORCID:0000-0001-5577-8387

Email: sangdonlee@gmail.com.

RUNNING HEAD: Inescapable inequality: *K* with r

Author Note

The authors received no financial support for this article's research, authorship, and publication.

Abstract

Thomas Piketty stated that widening economic inequality is an inevitable consequence of free-market capitalism, in which the rate of return (r) on capital (*K*) exceeds the rate of economic growth (*g*): $r > g$. Five System Dynamics models are developed to understand the underlying structure that causes economic inequality; *K* with *r*, which leads to the facts that *K* and capital income (Y_k) exceeds national income (*Y*): $K \gg Y$ and $Y_k \gg Y$ as time goes on. The Solow-Swan model, a fundamental reference for economic growth, describes the progressions of capital per capita (k) and income per capita (y). However, its focus on the *k*, *y*, and the key equation, $dk/dt = sy - (g_L + g_A + \delta)k$, obscure the fact that the $K \gg Y$ even when *k* and *y* are declining. We modified the Solow-Swan model to validate the claims by Piketty, $\beta = K/Y \rightarrow s/g$. Finally, a new mortgage payment scheme called CPPI (Constant Principal and Interest Payments) is proposed as a potential solution to mitigate economic inequality.

Keywords: Economic inequality, Piketty, $r > g$, Solow-Swan model, personal and national economic growth, taxes, *K* with *r*.

Introduction

Economic inequality, the unequal distribution of capital or wealth (*K*) and income (*Y*) among individuals or nations, has been worsening in recent years. The richest 1% of people owned 40% of world's assets in 2010. The three richest individuals in the world have more financial assets than the bottom 48 nations combined. The 85 wealthiest individuals in the world have as much wealth as the bottom 50% of the world's population (about 3.5 billion people). In the United States, the richest 1% holds 38% of all privately held wealth, while the bottom 90% held 73% of all debt (Oxfam, 2020, Jonathan et. al., 2019).

Thomas Piketty found that economic inequality has been widening considerably since 1990 (Piketty, 2013). He argues that widening economic inequality is an unavoidable outcome of free-market capitalism, where the rate of return (*r*) on *K* is greater than the growth rate of the economy (*g*): $r > g$. He found that *K* has been growing historically at a rate of 4 ~ 5% per year, while the economy has grown at a rate of 1 ~ 1.5% per year for the past hundred years. The two historical growth rates ~~by Pikett~~ty indicate that *K* doubles every 14.4 years (a 5% growth rate) while *Y* doubles every 48 years (a 1.5% growth rate). Therefore, the wealth owned by ~~a~~ nation or capital owners grows much faster than the wage earners and as a result, economic inequality inevitably becomes grows wider over time. The doubling time (years) can be approximately calculated by dividing 72 by the annual growth rate. He asserted that ultimately, this inequality would be the gap between people who inherit large sums of money and those who do not. He recommended that the best solution is a coordinated global effort to tax *K*.

Joseph Stiglitz stated that the use of political power gained by *K* explains the growing inequality much better (Stiglitz, 2015). He stated that economic inequality translates into political inequality, which in turn leads to even more economic inequality (a snowball effect) by making government policies financially beneficial to the people who have much wealth. This observation is known as rent-seeking behavior (by rent, profits, dividends, royalties, lobbying, etc.) in economics (Krueger, 1974). Rent-seeking behavior, an inappropriately labeled term, refers to the phenomenon of manipulating a system to favor a specific group rather than creating new wealth.

The goal of this paper is to understand the inescapable structure that inevitably leads to economic inequality for micro and macro economies. Five models are developed in sequence, starting from a simple personal economic growth model to a complex national economic growth model. We call them as KY-Micro and KY-Macro models, emphasizing the two state variables, K and Y. We modified the Solow-Swan model to show the structural similarity between personal economic and national economic growth models and to validate the claims by Piketty, $\beta = K/Y \rightarrow s/g$. Finally, we propose a new mortgage system called CPIP (constant principal and interest payments) as a solution to address economic inequality due to the free movement of finance and frequent job reallocation across national boundaries.

Micro-economic growth models (*KY-Micro*)

Three system dynamics (SD) models are developed to understand the inescapable structure that causes economic inequality. These models suggest that *capital accumulation* is the key contributing factor to economic inequality as K has two compounding growths while Y has only one. The first growth comes from the compounding growth (g_Y) of Y and the second from the compounding growth (r) of K. This results in the following chain of compounding growth in K: (1) $Y \rightarrow s\ (saving\ rate) \rightarrow K \rightarrow Y \rightarrow K,$ (2) $K \rightarrow\ Y_K(capital\ income) \rightarrow K \rightarrow\ Y_K.$ Thus, economic inequality is inescapable in the current economic system between individuals or nations who can and cannot accumulate K.

- The first model (*KY-Micro₁*) describes the feedback structure among Y, K, and Y_K. An individual earns Y, and a portion of Y is saved after living expenses and taxes are paid. The Y will grow with g_Y, and K will grow with a return of r, earning Y_K. Simulations show that K and Y_k will be larger than Y as time goes by if the saving rate is positive (s). The KY-Micro model shares a very similar structure with the Solow-Swan growth model, making it useful for understanding the economic inequality at the national level.
- The second model (*KY-Micro₂*) introduces three additional factors — income tax (IT), capital tax (CT), and capital income tax (CIT) — to the first model, aiming to comprehend the impacts of taxes on economic inequality. Simulations indicate that these taxes serve as effective measures to mitigate economic inequality. Income tax reduces available funds for investment or saving which will increase K.
- The third model (*KY-Micro₃*) analyzes how economic inequality widens between two groups—those with K and those without K—even though they initially began under the same structure. Simulations show that small differences in g_Y, s, r, or tax rates lead into $K \gg Y$ and $Y_k \gg Y$ due to astounding compounding effects. The people with K (the rich) own almost all wealth and pay almost all taxes. The K and Y for the poor grow over time but the rich grow much faster, thus economic inequality becomes wider. Simulations also reveal that faster accumulation of K has an unintended consequence of depleting natural resources quicker, especially in the later years of astounding compounding growth.

Macro-economic growth model (*KY-Macro*)

The Solow-Swan model (Solow, 1956, Swan 1956) is an important model that serves as a basis to understand macroeconomic growth by looking at national Y, K, population (L), and productivity (A). The model explains the national economy in per-capita terms, where $k = K/L$

and $y = Y/L$, to normalize the difference in population size. This may result in an unintended consequence; the focus on k and y obscures the fact that (1) K, Y, and Y_K will continue to grow exponentially, (2) $K \gg Y$, and (3) $Y_K \gg Y$ as time goes on even if the k and y decline. Therefore, without adequate guidelines or regulations, the economic inequality will continue to grow larger.

We modified the Solow-Swan model to show (1) the similar structure with the *KY*-Micro model, (2) $K \gg Y$ as time goes on, therefore, the gap among nations with or without K gets larger and thus some mechanisms such as global taxes on K are necessary to mitigate the economic inequality, and (3) to confirm the two laws suggested by Piketty; especially that the national capital-to-output ratio approaches to saving rate-to-income growth ratio ($\beta = K/Y \rightarrow s/g$). We call the modified Solow-Swan model as *KY-Macro* model, in which the dY/dt is derived. The Solow-Swan model treated Y as a flow and thus its derivative, dY/dt, is not derived. In SD, dY/dt is referred to as a flow variable while Y is called a stock variable. Simulations show that Piketty's claim on $\beta = K/Y \rightarrow s/g$ is satisfied if the national saving or investment is larger than labor or technology growth rates.

Constant Principal and Interest Payments (CPIP)

One of the results of globalization is that financial resources can be moved freely across national or regional boundaries, but people cannot. A recent survey showed that half of the single-family buyers stayed home for 6 to 9 years between 2001 and 2011 in the US and 13 years as of 2018 (Evangelou, 2020). Homeownership is one of the primary ways to build wealth. However, frequent reallocation and thus refinancing a mortgage is detrimental to wealth building because only a small amount of mortgage payments goes toward paying down the principal, especially in the early years. We propose a new mortgage system, called CPIP (constant principal and interest payments), in which constant amount is paid towards both principal and interest. This system can help those who frequently move by increasing the equity in their home, while still using compound interest for borrowing. Compound interest was once regarded as the worst kind of usury (unethical or immoral monetary loans that unfairly enrich the lender). For example, a 5% compound interest over 30 years is the same as 200% in simple interest.

The inescapable structure of economic inequality: *K* with *r*.

KY-Micro Model 1

To understand the inescapable structure of economic inequality for personal economy, the stock and flow diagram of the *K, Y*, and Y_K is shown in Figure 1 and the equations are described in Table 1. The units of measurements for variables are indicated after the @ symbol. A person earns *Y* which grows annually at a rate of g_Y and a portion of *Y* is saved after living expenses. The saving (*s*, $/year) increases *K* ($) which grows at a rate of r and earns Y_K ($/year). Notice that people with *K* have two compounding growths, while people without K have only one compounding growth; one is the increase in *s* from *Y* which grows exponentially with g_Y and the other is the Y_K from *K* itself which grows exponentially with r. Therefore, the gap in economic inequality between the people with *K* and without *K* will grow wider as time goes by. This is the inescapable nature of economic inequality; people with *K* or without *K*; $Y \rightarrow s \rightarrow K \rightarrow Y_K \rightarrow K$.

Case 1: Base run

The initial values for *Y* and *K* are 50K$ and 0$, respectively. The *r* is 7%, *s* is 20%, and g_Y is 3%. Both the *K* and *Y* grow exponentially and the $K \gg Y$ after 5 years and $Y_K > Y$ after 34 years (Figure 2). The gap between *K* and *Y* becomes larger and larger. After 34 years later, *K* grows to 2M$ while *Y* grows to 139K$/yr while *K* and *Y* grow to 15.2M$ and 302K$/year after 60 years, demonstrating the astounding growth in later years as time goes by.

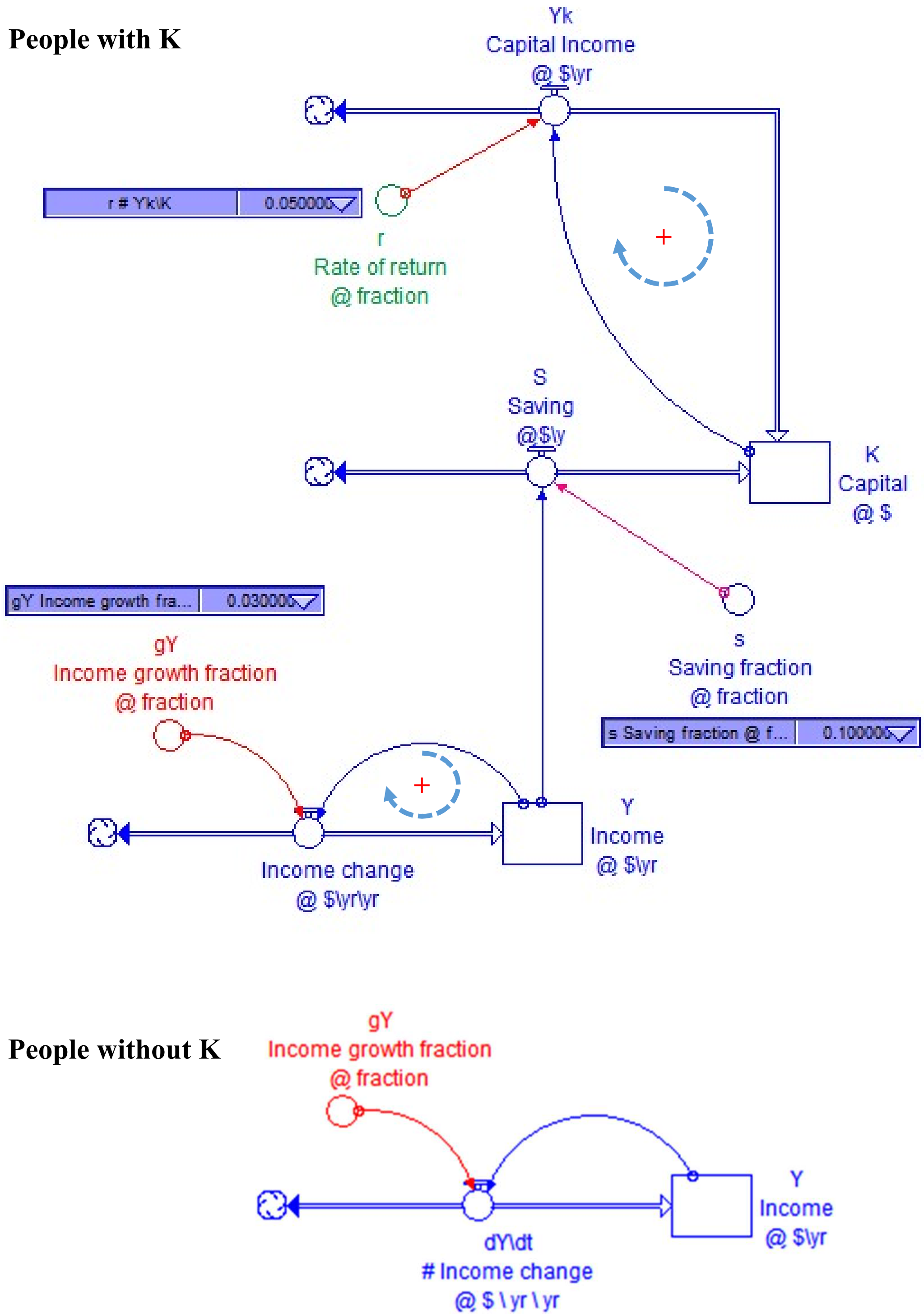

Figure 1. Inevitable structure of economic inequality: K with r (KY-Micro1). Two compounding growth factors, g_Y and r, contribute to the increase of K, resulting in $K \gg Y$.

Table 1. Personal economic growth model (KY-Micro)

Equations	No
$dY/dt = g_Y * Y$	(1)
$dK/dt = s * Y + r * K$	(2)
$Y_k = r * K$	(3)
$s = 20\%, \quad r = 7\%, \quad Y(0) = \$50K/yr, \quad K(0) = \$0.001$	(4)
$\beta = \frac{K}{Y}, \quad \alpha = \frac{Y_k}{Y} = \frac{r * K}{Y} = r * \left(\frac{K}{Y}\right) = r * \beta$	(5)
$g_Y = 3\% = \frac{\frac{dY}{dt}}{Y}, \quad g_K = \frac{\frac{dK}{dt}}{K} = \frac{s * Y + r * K}{K} = \frac{s}{\beta} + r$	(6)

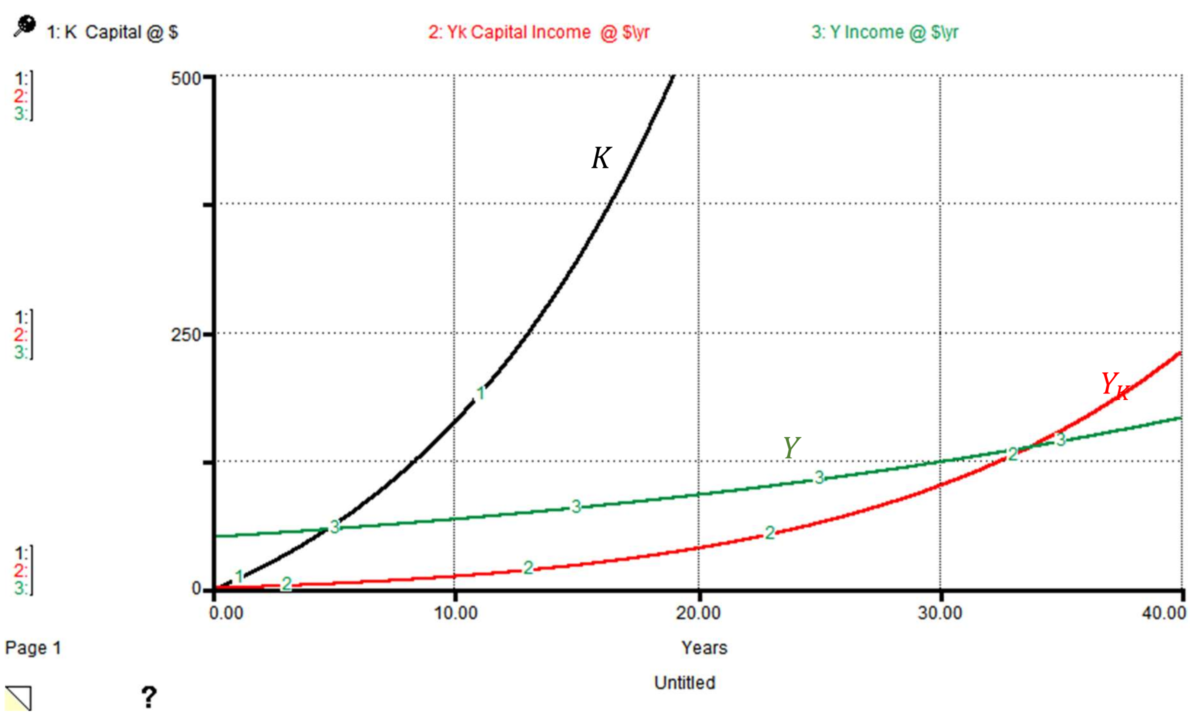

Figure 2. $K \gg Y$ *after 5 years and* $Y_K \gg Y$ *after 34 years even though K(0)=0$ and Y(0)=50K$/year initially. The gap between K and Y increases exponentially* $(r = 7\%, g_Y = 3\%, s = 20\%, K(0) = \$0, Y(0) = \$50K/yr)$.

Case 2: The *s* increased from 20% to 30%

The saving rate (s) is increased from 20% to 30%. The K and Y continues to increase exponentially; the $K \gg Y$ after 4 years and the $Y_K \gg Y$ after 27 years (Figure 3). The gap between K and Y goes to the singularity as time goes by. Y grows but K grows much faster. We computed the β and α for personal economic growth model even though they are meant for national economic growth model. Piketty suggested that the β will approach the ratio of s/g_Y for the *national* economy. The β and α grow exponentially, in which the β exceeds the s/g_Y after 21 years and the α exceeds after 74 years (Figure 4). Note that the year when β and α exceed the s/g_Y remains unchanged (21 and 74 years, respectively) even though the s is increased to various percentages (with s = 5%, 10%, 15%, 20%, 25%, 30%).

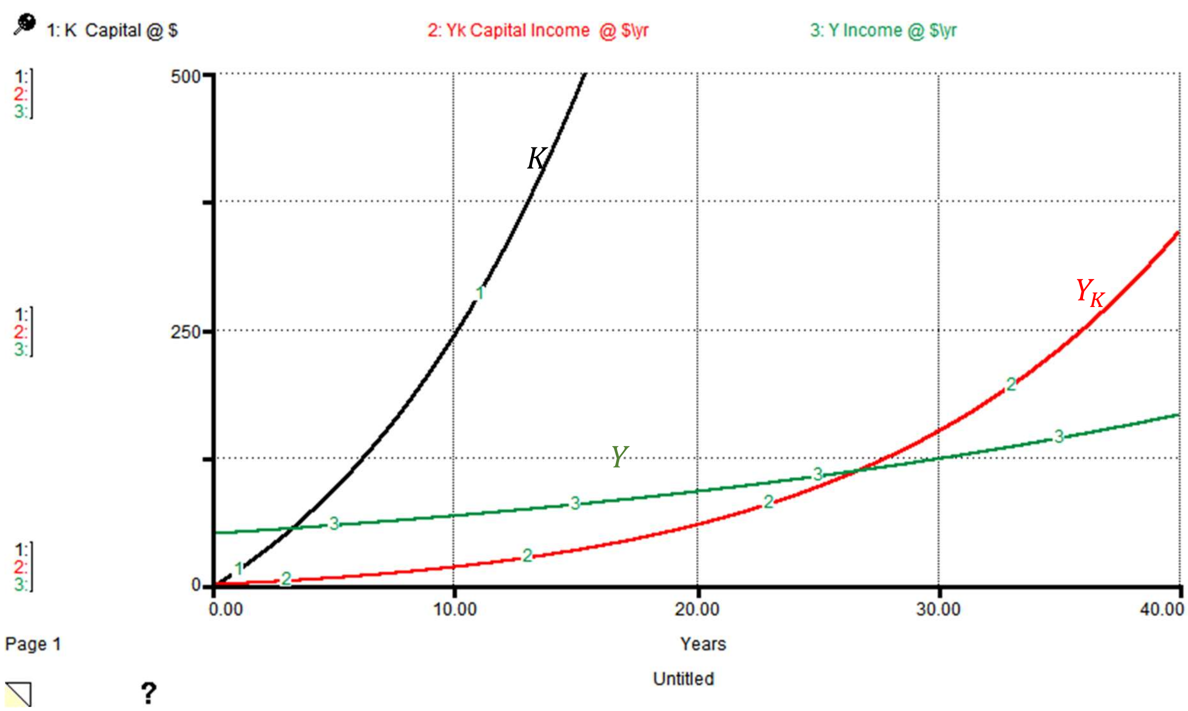

Figure 3. Increasing the saving rate from 20% to 30% accelerates both $K \gg Y$ and $Y_K \gg Y$ faster. The time it takes for $Y_K \gg Y$ is 27 years, compared to 34 years with a saving rate (s) of 20%.

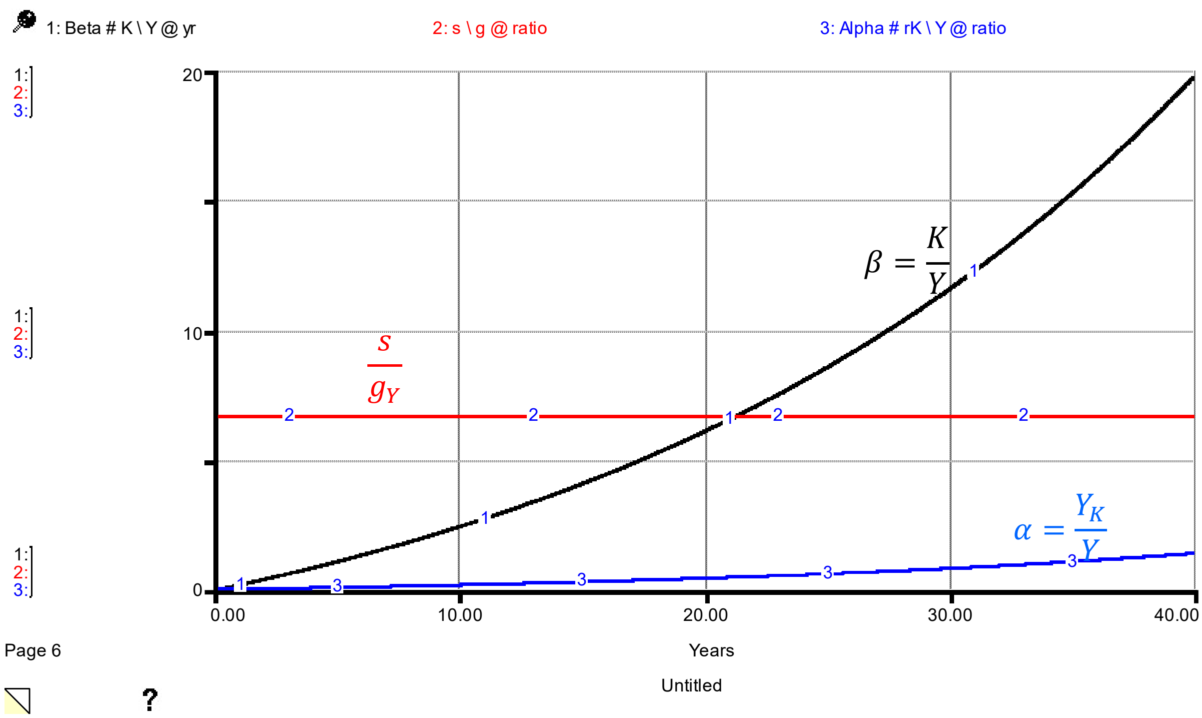

Figure 4. α, β, and s/g_Y. The $\beta = K/Y$ and $\alpha = Y_K/Y$ increase exponentially, indicating that $K \gg Y$ and $Y_K \gg Y$, respectively. The α and β exceed the s/g_Y in year 21 and 74 (r = 7%, g = 3%, s = 20%, and s/g = 6.67).

Case 3: g_Y and r

The two cases are analyzed whether $\beta = K/Y \to s/g$ or not by changing the g_Y and r; (1) r (7%) $>$ g_Y(3%) and (2) r (7%) $= g_Y$. If $r > g_Y$, then the α and β continue to increase exponentially while if $r = g_Y$, then α and β increase linearly (Figure 5 and Figure 6). For all cases, the $g_K \geq g_Y$ always (Figure 7 and Figure 8), that is, $r > g$ in Piketty's notation. Note that the K and Y will continue to grow and $K \gg Y$ even though economic measures such as g_K and g_Y reach steady state.

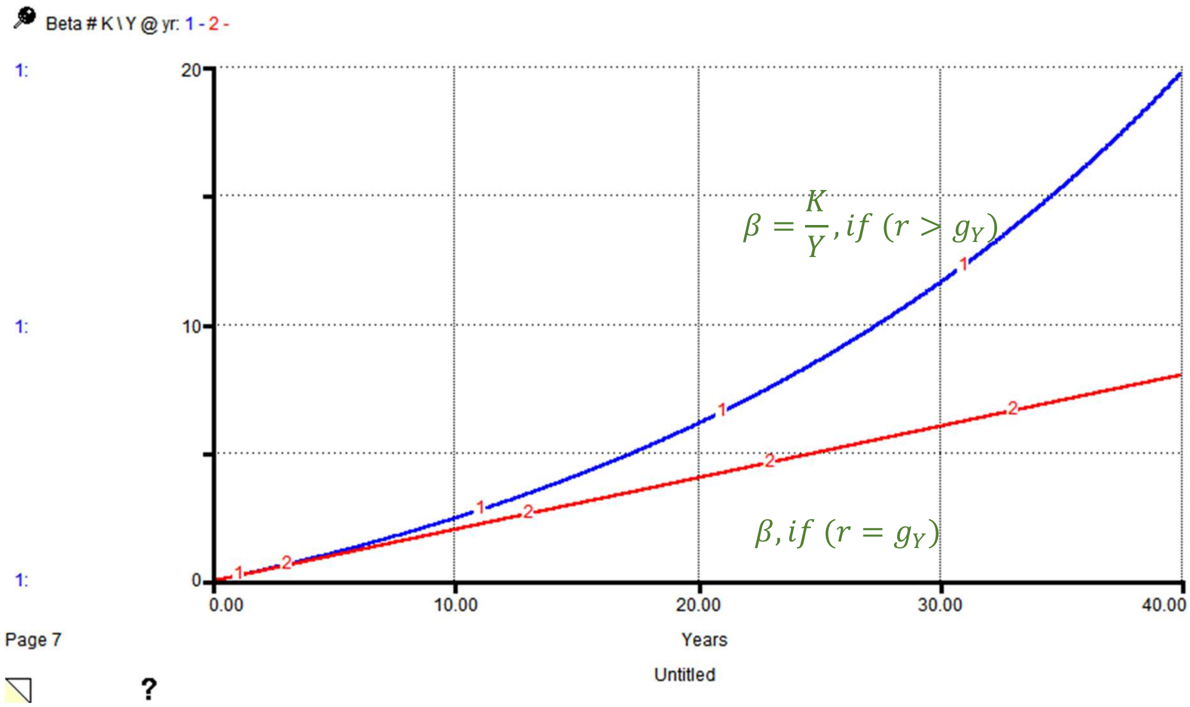

Figure 5. Two cases of β from (1) when r (7%) > g_Y (3%), and (2) when r (7%) = g_Y(7%) with the s= 20%. The β increases exponentially if r > g_Y, indicating $K \gg Y$ and β increases linearly if r = g_Y, indicating $K > Y$.

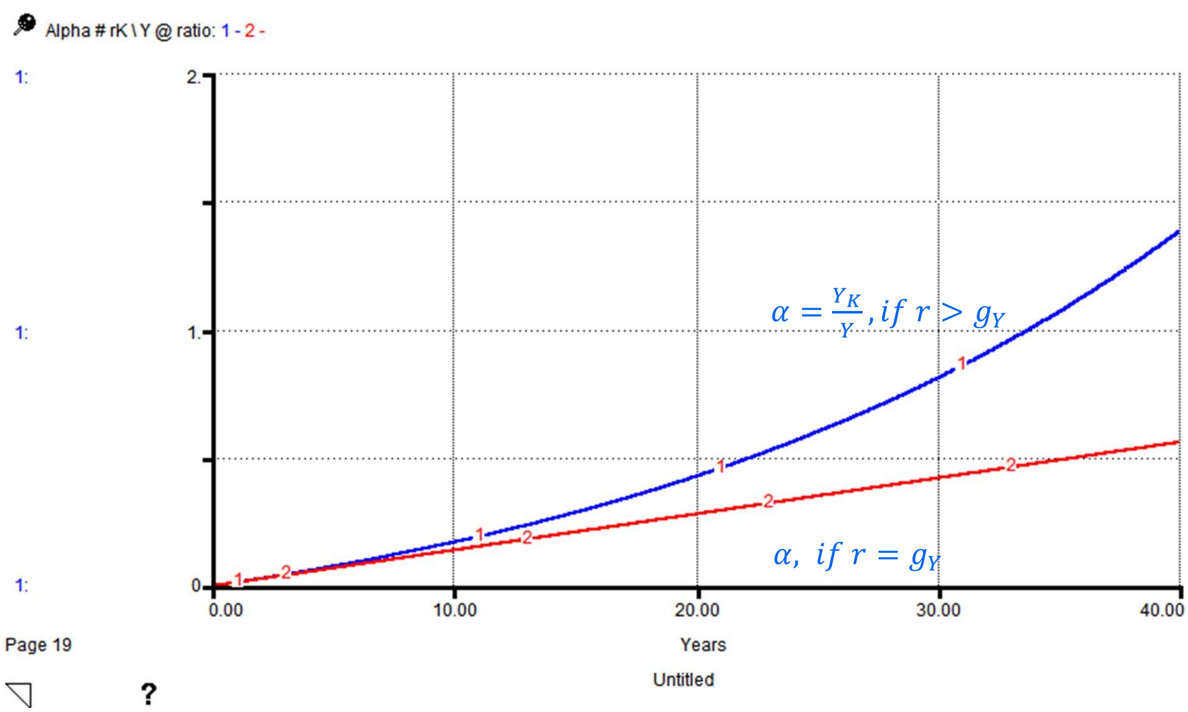

Figure 6. Two cases of α from (1) when r (7%) > g_Y (3%), and (2) when r (7%) = g_Y(7%) with the s= 20%. The α increases exponentially if $r > g_Y$, indicating $Y_K \gg Y$ and approaches a steady-state if $r \le g_Y$, indicating $Y_K > Y$.

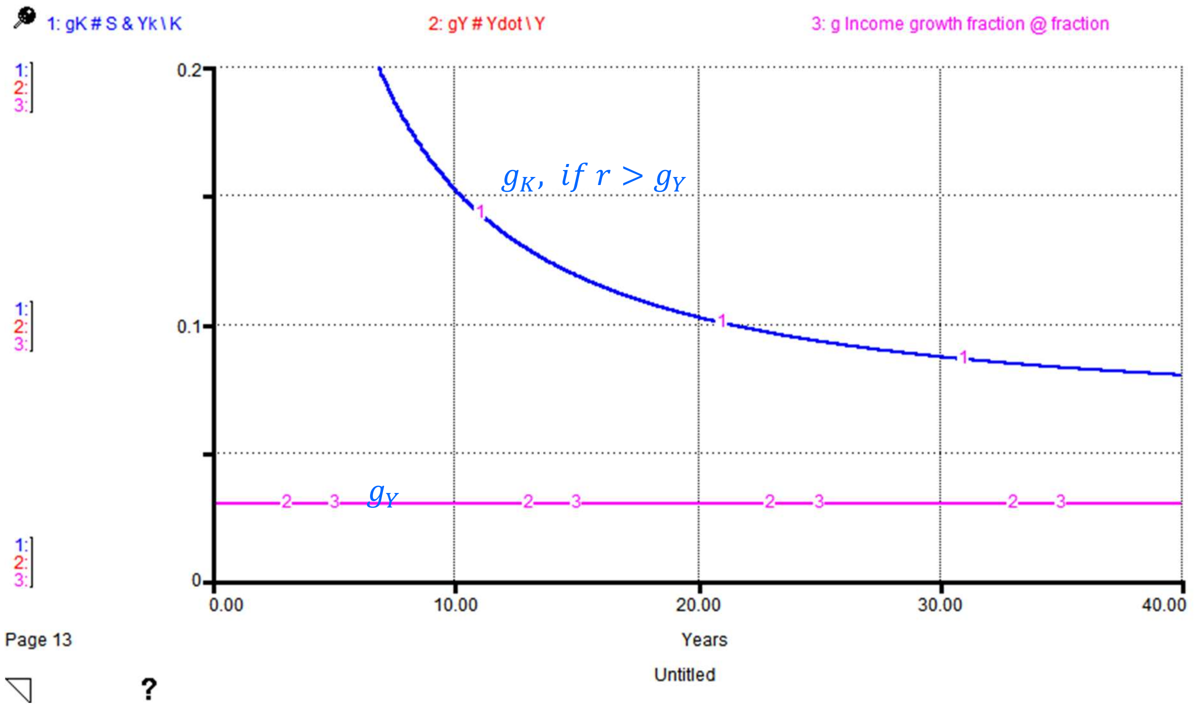

Figure 7. g_K *and* g_Y *with* r (7%) $> g_Y$ (3%) *and* $s = 20\%$. *The* g_K *approaches to* g_Y *but* $g_K > g_Y$ *always. The growth rate* g_K *includes both* Y_K *and* s.

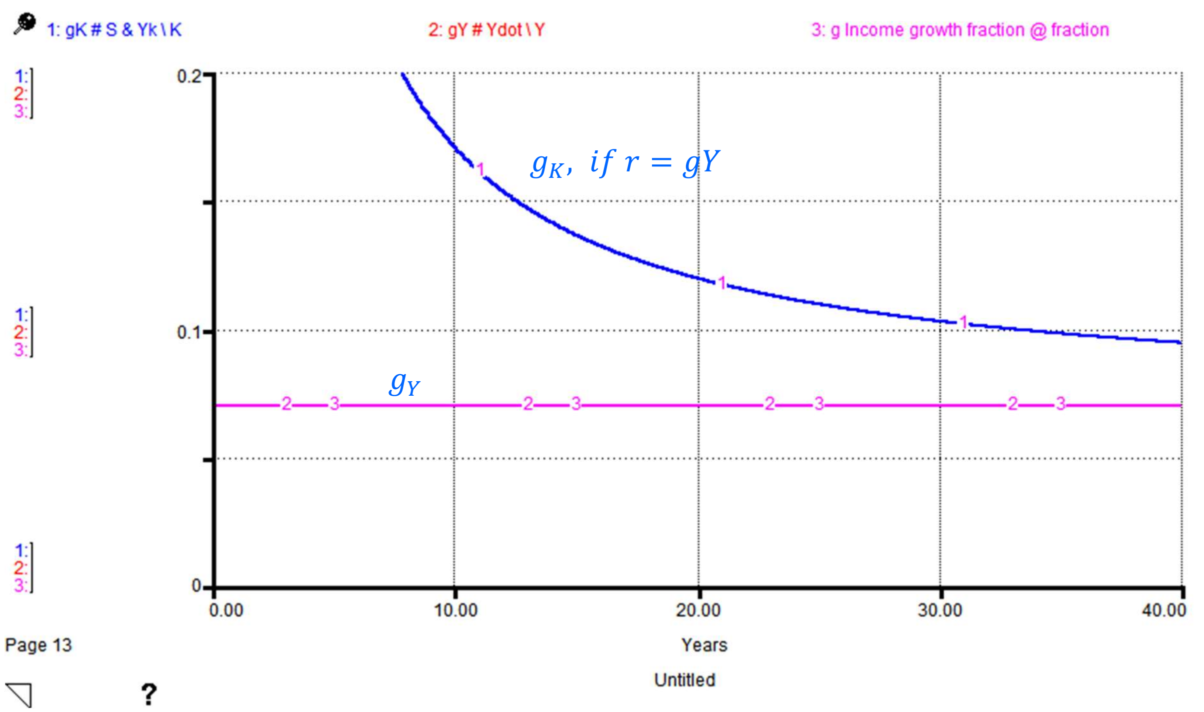

Figure 8. g_K *and* g_Y *with* r (7%) $= g_Y$(7%), *and* $s = 20\%$. *The* g_K *approaches to* g_Y *faster but* $g_K > g_Y$ *always.*

The effects of three taxes (*KY*-Micro2)

Three taxes are added to the first model; IT, CIT, and CT (Figure 9) and simulations are run after each tax is increased by 20%. The inescapable facts of the ever-widening gap between *K* and *Y* remains unchanged but the 3 taxes reduce the difference between them. The *K* and *Y* continue to grow exponentially, and *K* >> Y and Y_K >> *Y* as time goes by (Figure 10 and Figure 11).

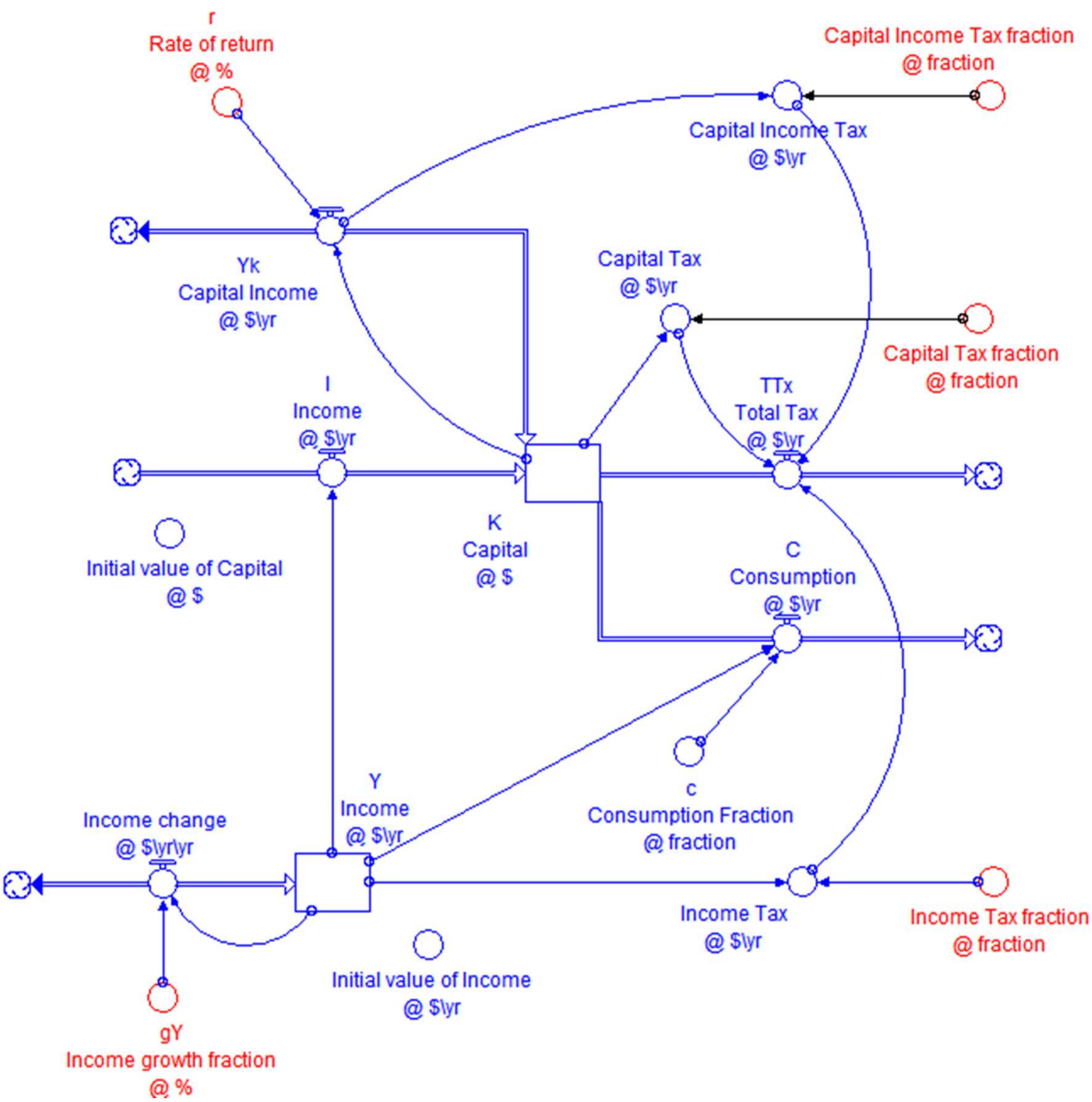

Figure 9. Three taxes and consumption are included (KY-Micro2). Inevitable structure of economic inequality: K with r (KY-Micro1) remains unchanged.

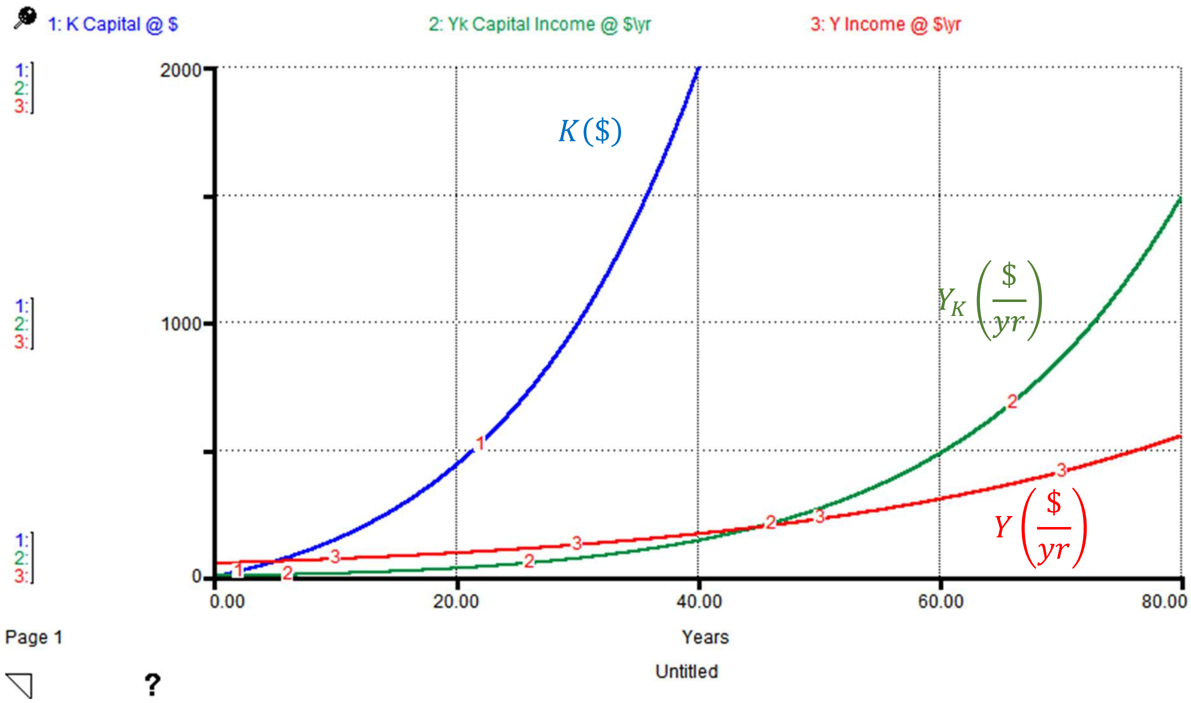

Figure 10. K, Y_K, and Y. $K \gg Y$ and $Y_K \gg Y$ *exponentially as time goes by (r=7%, gY=3%, c=55%, s=20%, IT=25%, CT=1%, CIT=15%).*

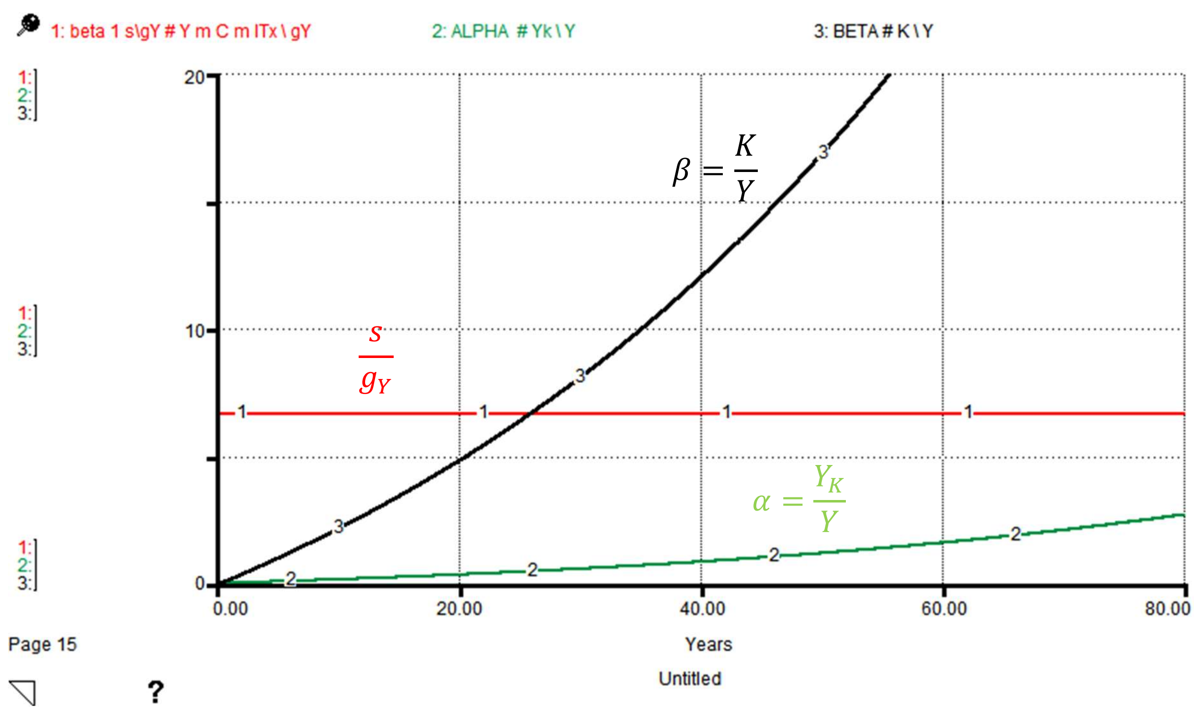

Figure 11. α, β, and s/g_Y with $r = 7\%$. *The* α *and* β *continue to increase and exceeds* s/g_Y.

The rich and the poor (*KY*-Micro3)

The economic inequality between two groups, the rich and the poor, is analyzed. Both groups have the same structure and initial parameter values and we changed one parameter at a time for the rich (Figure 12). Three new variables are added; the wealth of the world (WoW) which represents the total wealth created by economic activities such as mining, agriculture, and manufacturing, and is replenished by taxes and living expenses paid by the two groups. The WoW will be depleted if the wealth creation is smaller than the compounding growths of Y and Y_K. The second new variable added is rent-seeking behavior, which represents the feedback loops where economic inequality leads to political inequality and further economic inequality. The effects of rental seeking behavior are the same as various parameters are beneficial to the rich (e.g., income growth rate of the rich is higher than that of the poor). As the rich gain more wealth and political influence, their g_Y, r, s, will be higher than those of the poor, and they will be able to influence laws to reduce taxes or improve financial management. The third new variable added is inheritance taxes and we assume that the rich and the poor pay inheritance taxes every 25 years.

The simulations show that if the net flow to the rich is higher than that of the poor, the economic inequality will continue to grow exponentially, demonstrating the power of compound growth. Small differences in any one of these parameters (g_Y, s, r, tax rates or initial values) will lead into significant differences in K, Y, and Y_k over time, with the relationship being $Y \rightarrow s \rightarrow K \rightarrow Y_K \rightarrow K$. Higher Inheritance tax for the rich can reduce the rate that the economic inequality grows, but the gap between the rich and the poor continues to grow exponentially.

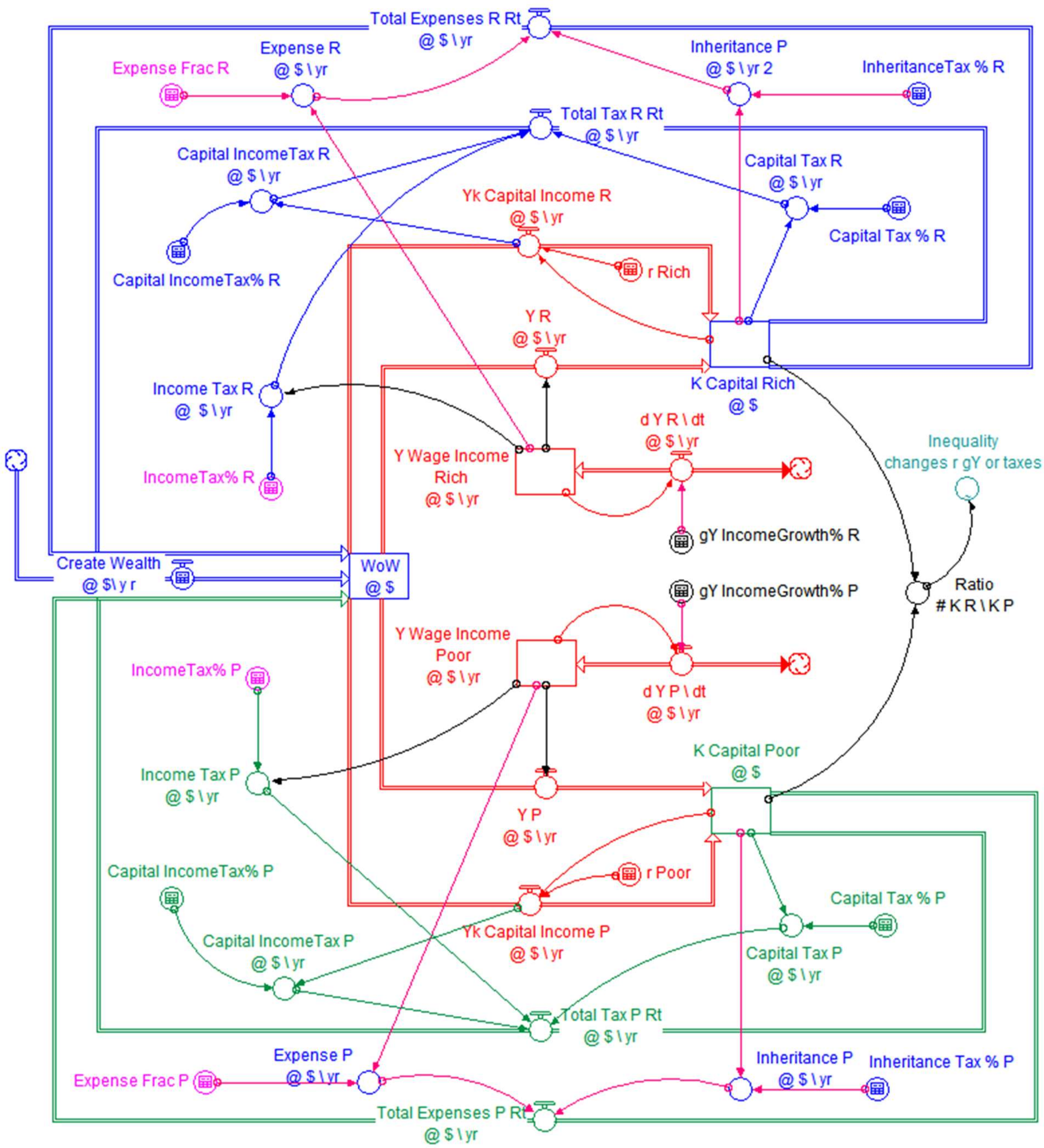

Figure 12. The Rich and the Poor (KY-Micro3). They have identical structures but varying parameter values. Small differences in any of these parameters (g_Y, s, r, tax rates or initial values) will lead into significant differences in K, Y, and Y_k over time.

Case 1: Base run

The initial values and parameter values are as follows and simulated for 200 years; *r* (4%), g_Y (4%), *s* (10%), *c* (70%), IT (20%), CIT (20%), CT (1%), inheritance tax (0%), *K* (0)

=100, Y (0) =100, WoW (20000$), $\frac{d}{dt}WoW$ =2000 ($/yr.). The initial value for WOW and the rate that WoW is created are intentionally set low so that the increased outflows from the WoW will deplete itself within the simulation time of 200 years. Inheritance tax is set to zero in the base run and is 25% for every 25 years for other runs. The capital for the rich (K_R) and capital for the poor (K_P) are set at 100 as well as Y_R and Y_P (Figure 13). The base run is to set that K, Y and Y_K are identical between the rich and the poor so that all economic measures between them are the same; $g_K^R = g_K^P,\ g_Y^R = g_Y^P,\ \beta_R = \frac{K_R}{Y_R} = \beta_P = \frac{K_P}{Y_P}, \frac{s_R}{g_Y^R} = \frac{s_P}{g_Y^P}$.

Simulations show that $K \gg Y$ and, $K_R = K_P$ and $Y_R = Y_P$ (Figure 13). The WoW reaches the maximum value at year 100 and deplete quickly at 140 years. It takes 100 years to reach the maximum but only 40 years to deplete due to the astounding exponential growth at the later years. The g_K approaches the steady state of the g_Y (Figure 14). The $\beta_R = K_R/Y_R = \beta_P = K_P/Y_P$, exceeds the s/g_Y in year 25, and approach to the steady state (Figure 15). Even though various economic measures reach to steady state, the *K* and *Y* continue to increase exponentially and $K \gg Y$, thus the gap between nations or people with and without *K* will continue to grow.

Case 2: All parameters for the rich are 50% higher

All parameters and initial values for the rich are 50% higher than those of the poor; *r* (6% for the rich vs. 4% for the poor), *K* (150$ vs. 100$), *Y* (150 $/year vs. 100 $/year), CIT (30% vs. 20%), IT (30% vs. 20%), CT (1.5% vs. 1%), g_Y (6% vs 4%), *s* (10% vs. 10%), WoW (0) = 20000, $dWow/dt$=2000. The simulation shows that the rich own almost all *K, Y* and Y_K (Figure 16 and Figure 17) and pay almost all taxes (Figure 18). The gap between them gets wider as time goes by. The *K, Y* and Y_K for the poor increase, but the gap between the poor and rich grows wider and wider.

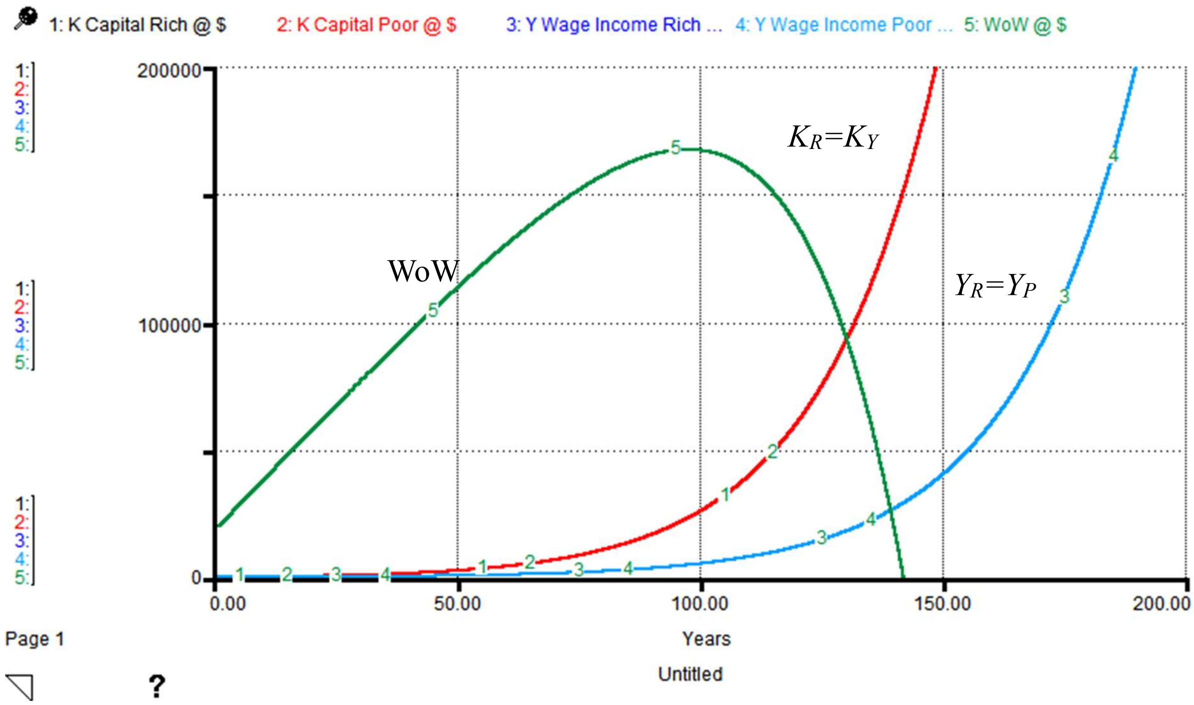

Figure 13. K, Y, Yk for the rich and the poor and WoW (base run). All parameter and initial values are identical between the rich and the poor ($K_R = K_P$ and $Y_R = Y_P$). The initial value of WoW is set to deplete within 200 years .

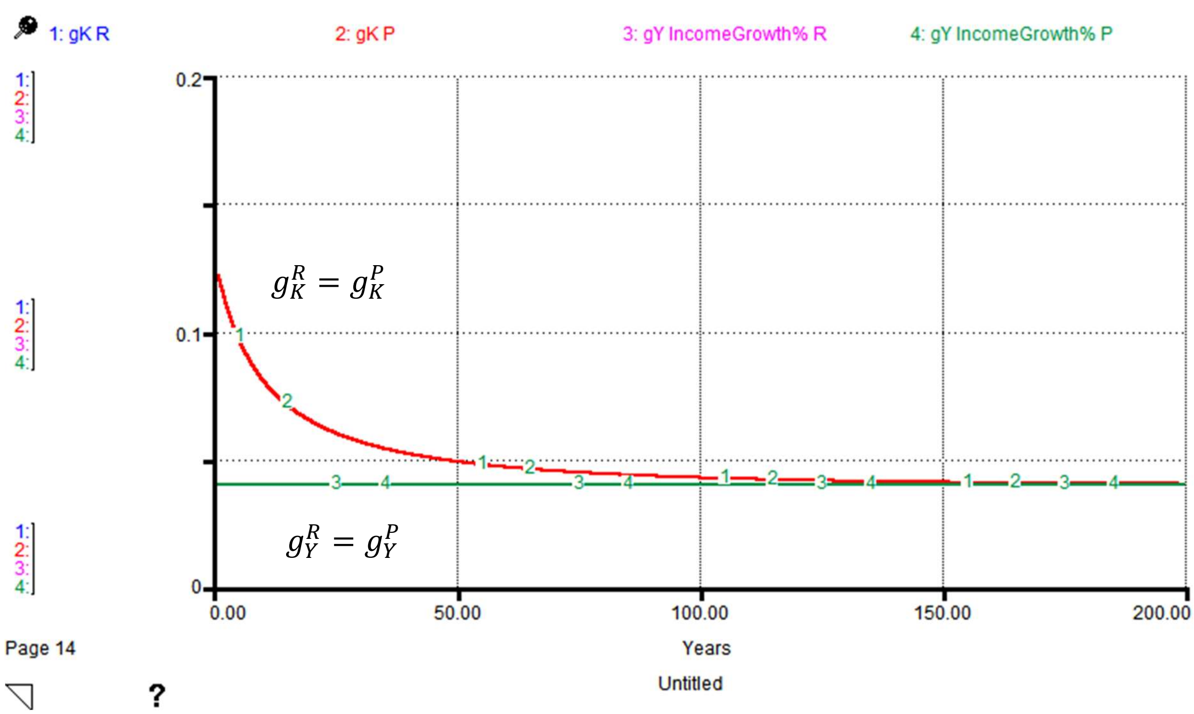

Figure 14. g_K and g_Y for the rich and the poor (base run). $g_K^R = g_K^P$ and $g_Y^R = g_Y^P$. The g_K approaches to g_Y and reach steady state.

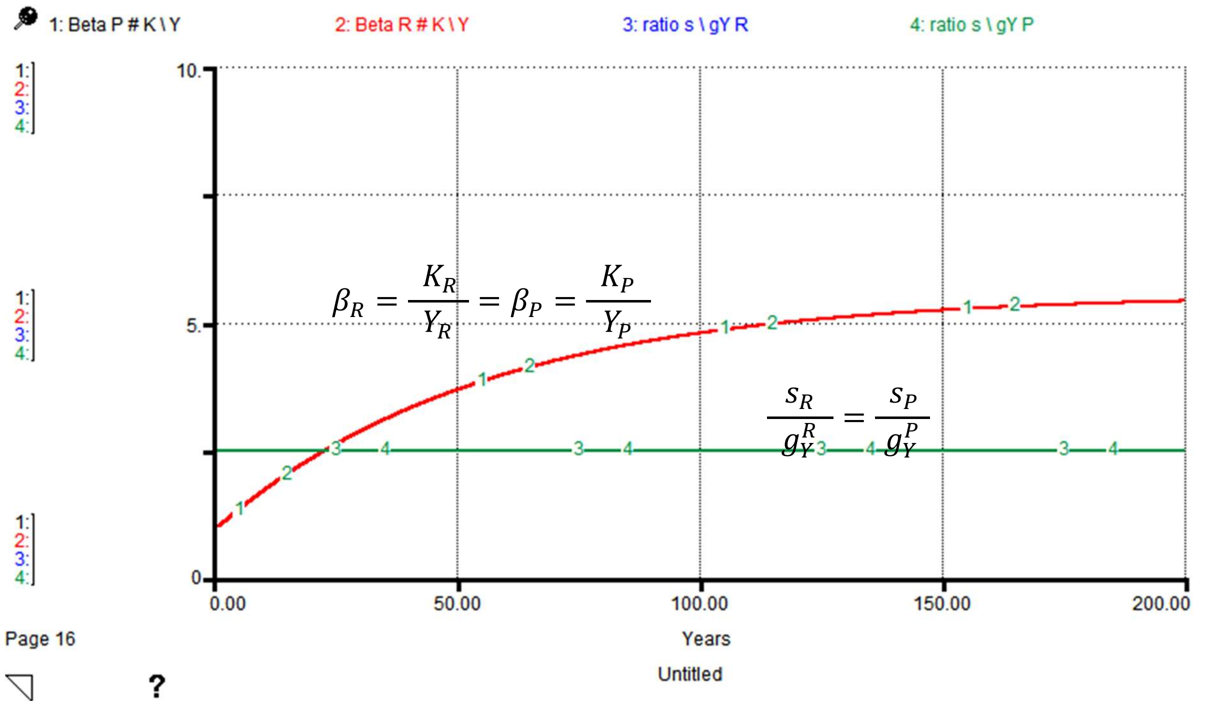

Figure 15. β *and* s/g_Y *for the rich and the poor (base run). The* β *exceeds s/gY and reach to steady state, indicating K>>Y.*

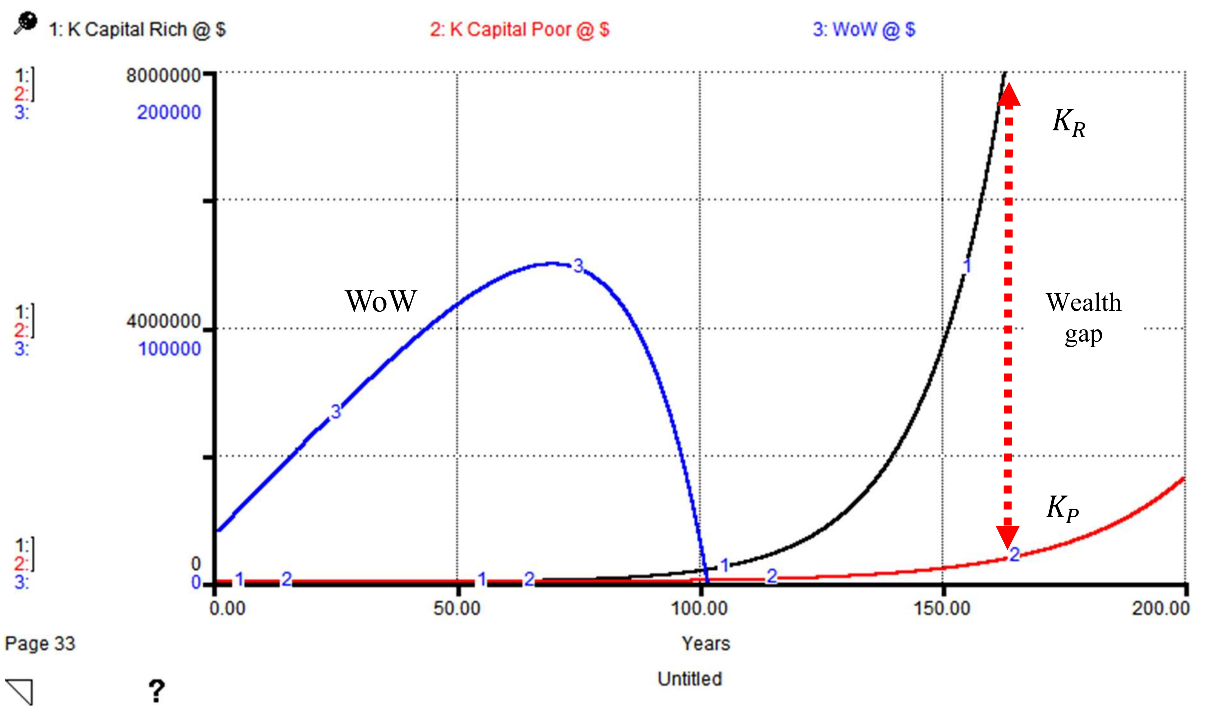

Figure 16. K, Y, Yk for the rich and the poor and WoW (case 2). The rich own almost all K and $K_R \gg K_P$*. All parameters for the rich are 50% higher than those of the poor.*

Figure 17. Y_R, Y_P *for the rich and the poor and WoW (case 2). The rich own almost all Y and* $Y_R \gg Y_M$

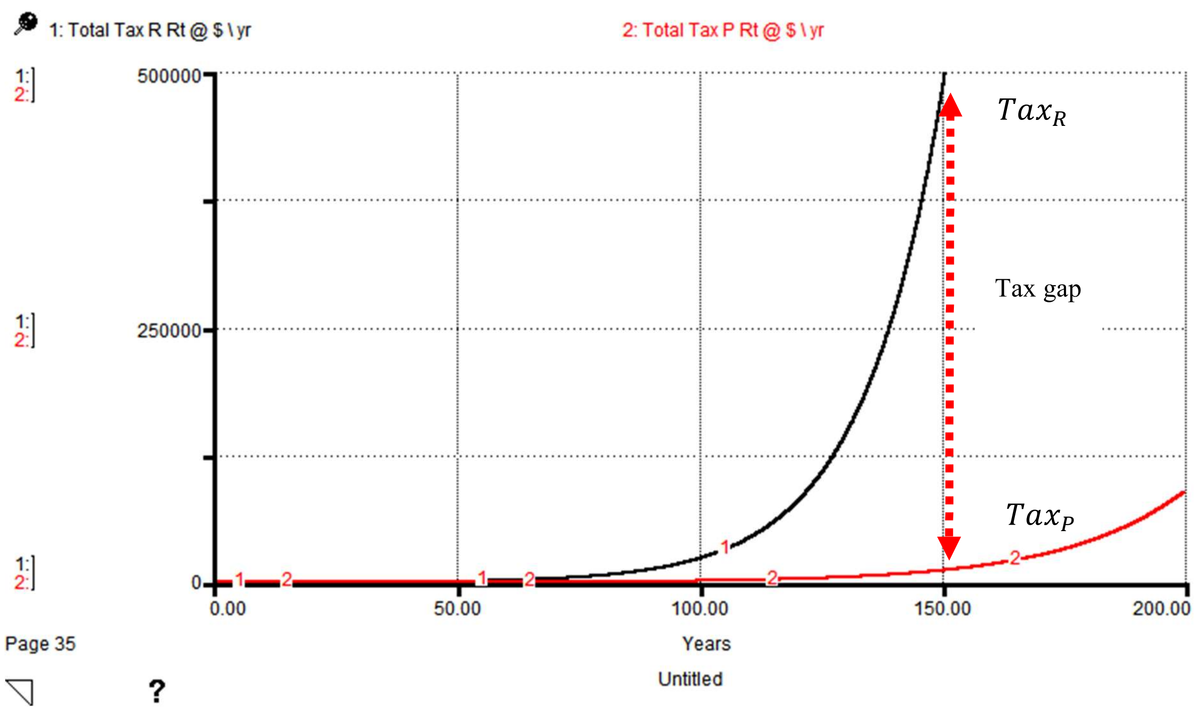

Figure 18. Total tax paid by the rich and the poor (case 2). The rich pay almost all taxes and $Tax_R \gg Tax_P$.

Case 3: g_Y^R is increased from 4% to 5%

Only the income growth rate for the rich, g_Y^R, is increased from 4% to 6% (50% higher than that of the poor) and all other initial and parameter values are identical between them. The increase in g_Y^R leads to income inequality and wealth inequality (Figure 19) because $g_Y \rightarrow Y \rightarrow s \rightarrow K \rightarrow Yk \rightarrow K$ and the gap between the two group gets wider ($K^R \gg K^P$, $Y^R \gg Y^P$, $Y_K^R \gg Y_K^P$). This simulation shows that any higher parameter or initial values for the rich will lead into economic inequality.

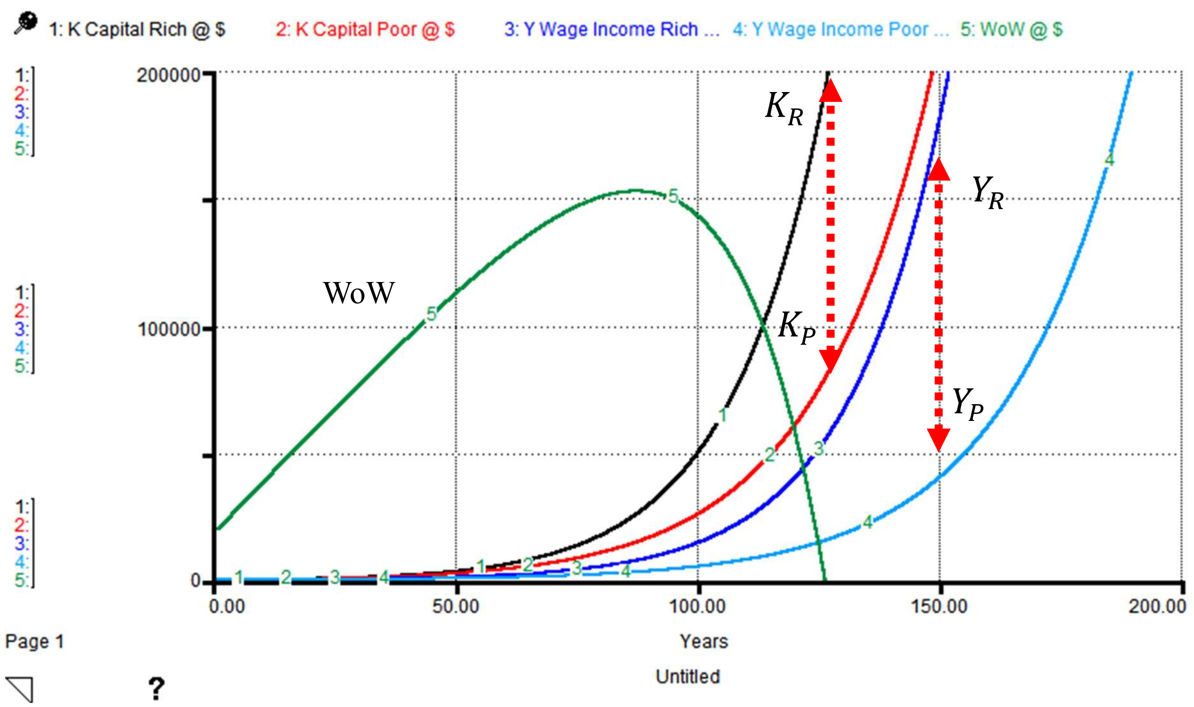

Figure 19. K, Y, Yk for the rich and the poor and WoW (case 3). The increased g_Y^R from 4% to 5% leads into $K_R \gg K_P$ and $Y_R \gg Y_P$, demonstrating the widening economic inequality.

Case 4: Inheritance tax

The fourth case simulates the effect of inheritance taxes on economic inequality. For simplicity, it is assumed that the rich pay a 50% inheritance tax on K every 25 years, while the poor pay a 25% tax. The simulation shows that the inescapable structure of economic inequality persists over generations although the gap between the rich and the poor is slightly smaller than in the base run ($K^R \gg K^P$ in Figure 20). Inheritance will replenish the WoW and delay its depletion, but the WoW will eventually be depleted. The fact that the rich will own most of the K and pay most taxes remains unchanged.

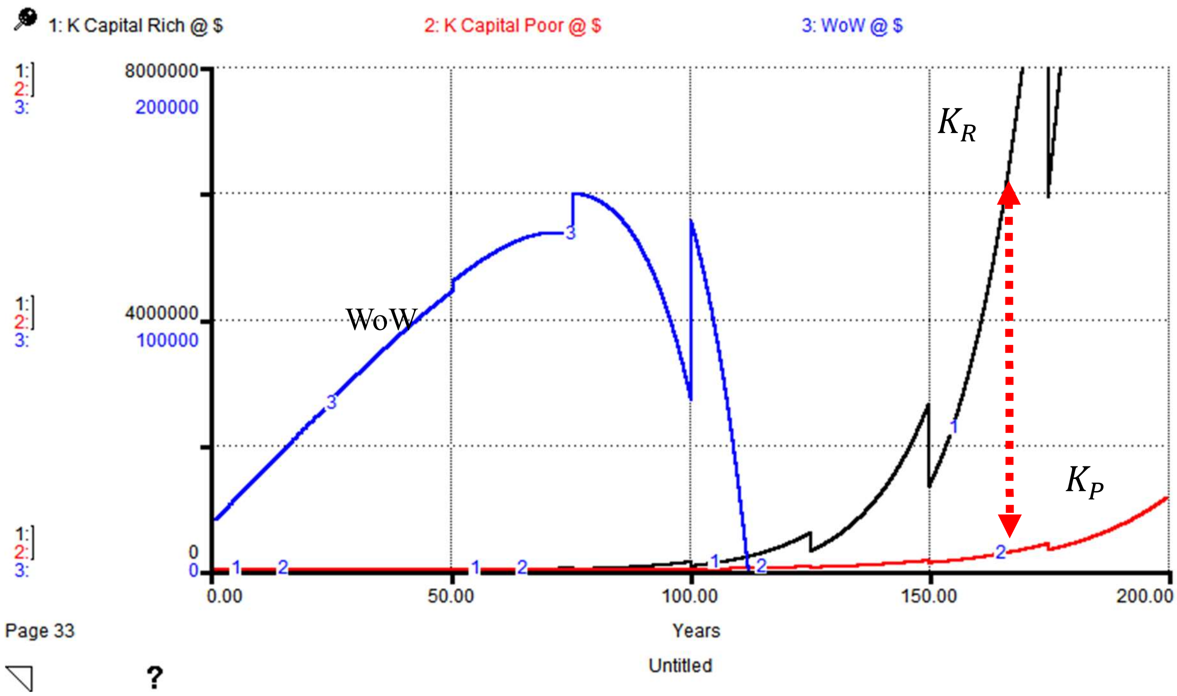

Figure 20. Effects of inheritance tax on K for the rich and the poor and WoW (case 3). The widening gap between the rich and the poor remains unchanged: $K_R \gg K_P$. The inheritance tax delays the depletion of WoW, compared to the base case but the WoW depletes eventually.

Summary of simulation results from *KY*-Micro

The accumulation of K is the key factor in causing economic inequality because it leads to two compounding growths. The first growth is $g_Y \rightarrow Y \rightarrow s \rightarrow K \rightarrow Y_K \rightarrow K,$ a reinforcing feedback loop between K and Y_K. The second growth is $g_Y \rightarrow Y$, which increase the s and thus increases the K and Y_K. To reduce the economic inequality, increasing the growth rate of wage income and the rate of return from K for the poor are effective ways. Economic inequality is inescapable in the current economic system between people with *K* and people without *K*. The gap between them grows larger and larger as time goes by. Eventually, the rich will own almost all *K*, pay almost all taxes, and earn almost all *Y*. Piketty proposes a global system of progressive capital tax to help reduce economic inequality. The IT, CIT, and CT for the rich are effective ways of reducing economic inequality also and they have additional benefits of delaying the depletion of WoW because we assume that they are the inflows to WoW. The IT reduces the K, which will slow down the growth of K from the beginning. The CT will reduce wealth inequality.

Macro-economic growth model (KY-Macro)

Piketty's statement about $r > g$

The main arguments by Piketty and others for why wealth inequality is set to rise come from observations that the *r* from *K* have exceeded the g_Y for the last 100 years. Their collected data showed that the wealth-income ratio ($\beta = K/Y$) has been increasing since the 1970s (figure 3 in Piketty's paper) as well as income and wealth inequality (figure 1 and 2 in Piketty's paper), reaching the level before 1900. These observations are expressed as $r > g$. He stated two fundamental laws in his book. The first law is merely a definition; the share of capital income to national output (α) is equal to $r * \beta$. The second asserts that the share of *K* to *Y* will, eventually, approach to s/g.

- Law 1: $\alpha = \frac{Y_K}{Y} = \frac{r\,K}{Y} = r\left(\frac{K}{Y}\right) = r\,\beta,$ by definition. The α is the ratio of Y_K compare to Y and both are in \$/year.
- Law 2: $\beta = K/Y$ (by definition) approaches to the ratio of s/g. The β has a unit of measure as years ($K/Y = (\$/year)/year = year$).

Solow-Swan Model

The Solow-Swan model is the basic reference model used to explain the long-run economic growth. It attempts to model how the *Y* is created as a function of the *K*, labor (*L*), and technology (*A*). The key equation, $\frac{dk}{dt} = s\,y - (g_L + g_A + \delta)\,k,$ shows the behavior of the capital per capita, $k_2 = K/(A\,L)$ and the income per capita $y_2 = Y/(A\,L)$, while considering difference in population size among nations. The *k* is increased by investment ($I_t = s * Y_t$) and decreased by depreciation ($\delta * K_t$), labor growth (g_L), and technology growth (g_A). The *k* will be in equilibrium if dy/dt is equal to zero

$$\frac{dk_t}{dt} = \frac{d\left(\frac{K}{A\,L}\right)}{dt} = s\,y_t - (g_L + g_A + \delta)\,k_t \tag{6}$$

This key equation is derived from the following equations. The labor and population growths are exogenous and given by g_L and g_A, respectively.

$$\text{Let } Y = K^{\alpha}\,(A\,L)^{1-\alpha}, \tag{7}$$

$$L = L(0)\;Exp(g_L\,t), \text{ and } A = A(0)\;Exp(g_A\,t),$$

$$k_1 = \frac{K}{L}, and \;\; k_2 = \frac{K}{A * L}$$

$$y_1 = \frac{Y}{L}, and \; y_2 = \frac{Y}{A * L}$$

$$\text{By definition, } \frac{dY}{dt} = \dot{K} = s\,Y - \delta\,K \tag{8}$$

$$\frac{dY}{dt} = \dot{Y} = \alpha K^{-1+\alpha}(A\,L)^{1-\alpha} + (1-\alpha)K^{\alpha}(A\,L)^{-\alpha}\left(L\,\dot{A} + A\,\dot{L}\right)$$

$$= \{\alpha g_K + (1-\alpha) g_A + (1-\alpha) g_L\} Y$$

$$\dot{k_2} = \frac{dk}{dt} = \frac{d\left(\frac{K}{A*L}\right)}{dt} = -\frac{K\,\dot{A}}{A^2\,L} + \frac{\dot{K}}{A\,L} - \frac{K\,\dot{L}}{A\,L^2} \tag{9}$$

$$= -\frac{K\,\dot{A}}{A\,L\,A} + \frac{s\,Y - \delta\,K}{A\,L} - \frac{K\,\dot{L}}{A\,L\,L} = -k\,g_A + (s\,y - \delta\,k) - k\,g_L$$

$$= s\,y - (\delta + g_A + g_L)\,k_2.$$

$$\dot{k_1} = \frac{dk}{dt} = \frac{d\left(\frac{K}{L}\right)}{dt} = \frac{\dot{K}}{L} - \frac{K\,\dot{L}}{L\,L} = \frac{s\,Y - \delta\,K}{L} - \frac{K\,\dot{L}}{L\,L}$$

$$= s\,y - \delta\,k_1 - k_1\,g_L$$

$$\dot{y_2} = \frac{dy}{dt} = \frac{d\left(\frac{Y}{A\,L}\right)}{dt} \tag{10}$$

$$= -\frac{K^{\alpha}\,(A\,L)^{1-\alpha}\,\dot{A}}{A^2\,L} + \frac{\alpha\,K^{\alpha-1}\,(A\,L)^{1-\alpha}\,\dot{K}}{A\,L} - \frac{K^{\alpha}\,(A\,L)^{1-\alpha}\,\dot{L}}{A\,L^2}$$

$$+ \frac{(1-\alpha)\,K^{\alpha}(A\,L)^{-\alpha}\left(L\,\dot{A} + A\,\dot{L}\right)}{A\,L}$$

$$= (\alpha\,g_K - \alpha\,g_L - \alpha\,g_A)\,y$$

Unintended consequences of focusing on k and y, not K and Y.

The analyses of the Solow-Swan model focused on the behavior of *k* and *y*, not *K* and *Y*, to reflect difference in population size among nations [Acemoglu, 2009, Romer, 2011]. The typical behavior of *k* and *y* is shown in Figure 21 in which the *k* and *y* approach steady state (e.g., Romer, page 20, Figures 1.5 and 1.6). However, it is important to note that even though *k* and *y* reach a steady state or even decline, the *K* and *Y* will continue to increase exponentially, and more importantly, $K \gg Y$. Thus, the inescapable structure of economic inequality will continue to grow between the people and nations with and without *K*.

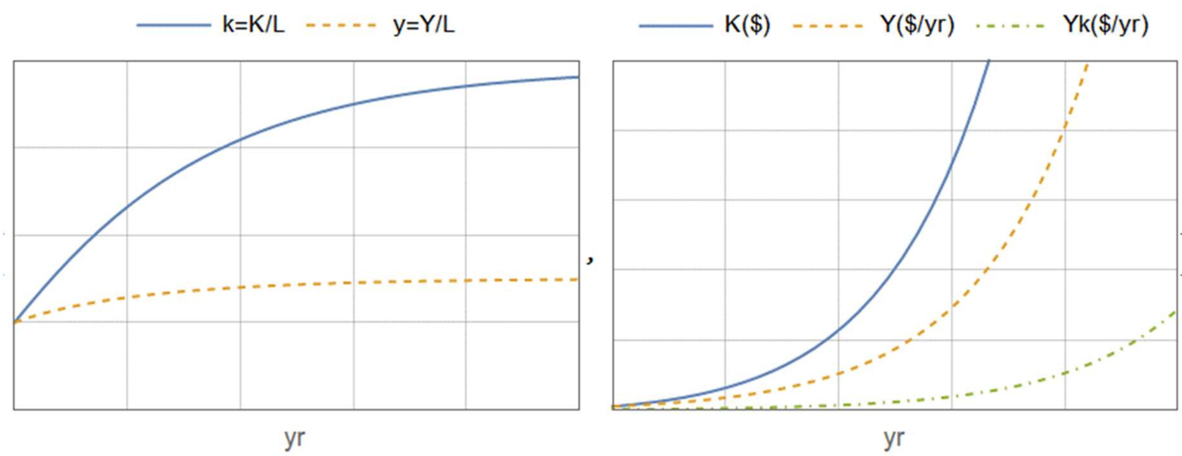

Figure 21. Typical shapes of the k and y from the Solow-Swan model that approach steady-state (left) even though the K and Y grow exponentially, indefinitely, and K ≫ Y (right). Economic inequality between people and nations with and without K continue to widen.

Cobb-Douglas production function

The key assumption of the Solow-Swan model is the functional form that determines how the three factors of production (*K, L, A*) affect the *Y*. A specific type of function called the Cobb-Douglas production function is widely used because of its mathematical properties that represent the economic relationship well (Acemoglu, 2009, Romer, 2011). The function assumes that as the *K, L,* and *A* increase, the *Y* will also increase but at a decreasing rate, meaning the marginal product of each factor will be positive but decreasing.

$$Y_t = f\ (K_t, L_t, A_t) = K_t^{\alpha} * (A_t * L_t)^{1-\alpha},\ \ \alpha + \beta = 1.$$

There are many forms of production functions available for analyzing economic output. Griffin et al. summarized the properties of 20 different functional forms of production functions (Griffin, et. al., 1987). One of the simplest form is a linear production function, e.g., $Y_t = c_K * K_t + c_L * L_t + c_A * A_t$ and thus $\frac{dY_t}{dt} = c_K * \frac{dK_t}{dt} + c_L * \frac{dL_t}{dt} + c_A * \frac{dA_t}{dt}$. One weakness of this production function is that if one of the factors such as *K, L,* or *A* becomes zero, *Y* does not become zero. This may not represent the case where lack of resources hinders production.

Additional factors can be added to the Cobb-Douglas production function such as R&D, education, etc., e.g., $Y_t = K_t^{\alpha} * A_t^{\beta} * L_t^{\gamma} * \ldots * H_t^{\eta}$.

KY-Macro model

Comparison between *KY*-Micro and *KY*-Macro models

The *KY*-micro and *KY*-macro models are very similar in terms of stock and flow variables but there are some differences between them. One difference is that the $Y_t = K_t^{C_K} * L_t^{C_L} * A_t^{C_A}$ for macro-economy while the $Y_t = Y(0) * Exp(g_Y * t)$ for micro economy. Another difference is that the *KY*-micro model includes financial or capital gain (e.g., income from investment on the stock market, or home). However, the Solow-Swan growth model and the *KY*-macro model do not include the financial gain due to the definition of *Y*. The definition of GDP or *Y* does not include financial gain, as these do not produce tangible outcomes. Despite this, financial gains from capital are a significant factor in economic inequality. The size of the financial stock market exceeds the national output in the US; "The combined market value of all U.S. stocks, as measured by the Federal Reserve, is now … *at 125% of GDP as of October 2016 (approximately $27,000 Billion)"* (Mislinski, 2020). Therefore, the financial gains from capital should be included to understand the economic inequality.

The Solow-Swan model is modified to confirm the two laws stated by Piketty; especially $\beta = K/Y$ approaches s/g (Figure 22 and Table 2). Note that the *k* and *y* can be easily computed by dividing *K* and *Y* with *L*. Several economic measures are also computed such as $\alpha, \beta, etc.$ Note that we use $Y_t = K_t^{C_K} * L_t^{C_L} * A_t^{C_A},\ \ c_K + c_L + c_A = 1$, while the Solow-Swan model typically use $Y_t = K_t^{\alpha} * (A_t * L_t)^{1-\alpha}$. We use g_K and g_Y while Piketty used *r* and g. The *A*L* is called effective labor.

$$Y_t = f\ (K_t, L_t, A_t) = K_t^{cK} * L_t^{c_L} * A_t^{cA}, \qquad c_K + c_L + c_A = 1$$

$$k = K_t/L_t \ and \ y = Y_t/L_t, k_2 = K_t/(A_t * L_t) \ and \ y_2 = Y_t/(A_t * L_t)..$$

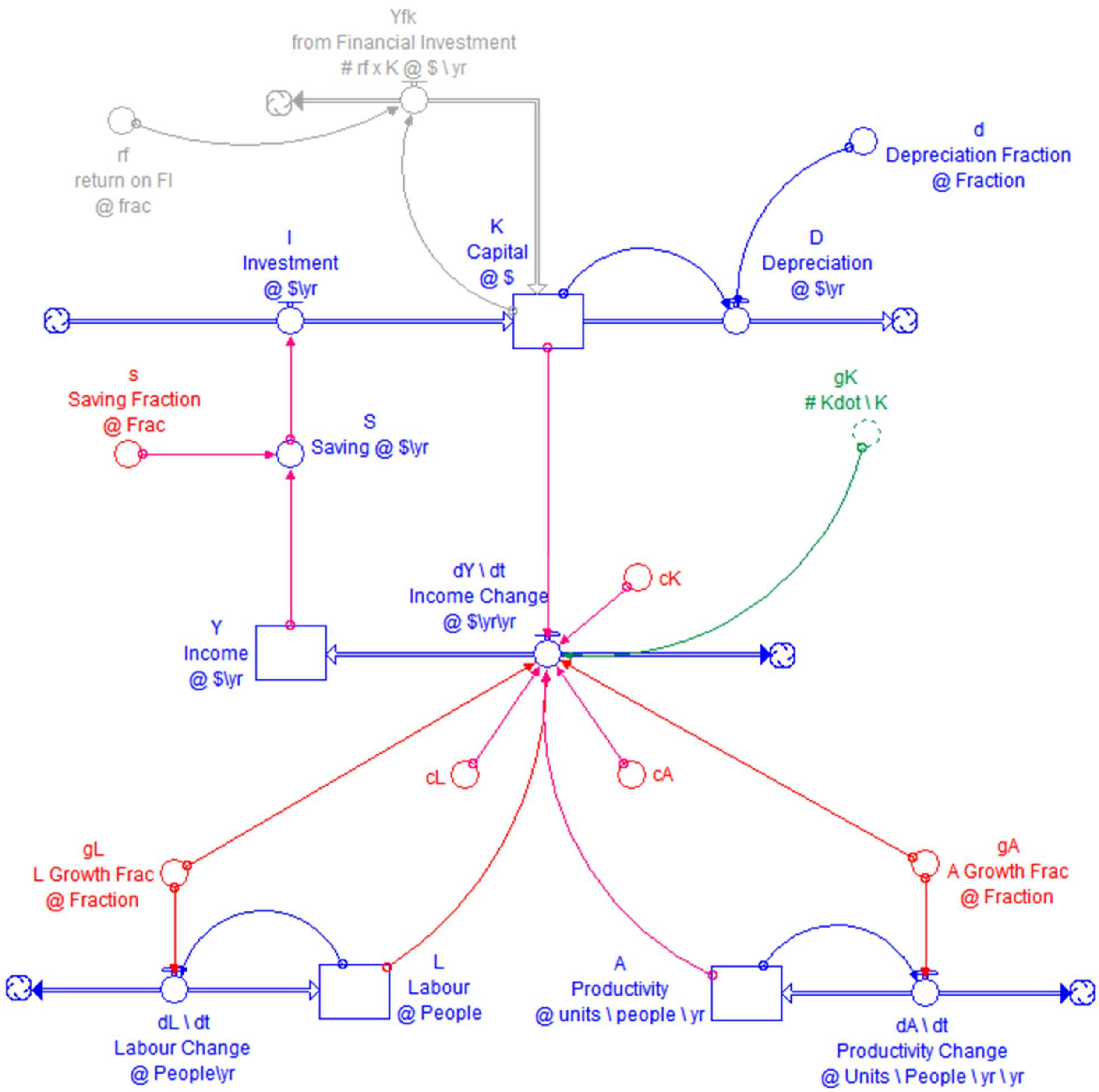

Figure 22. KY-Macro mode in which Y is modified as a stock variable and its derivative is derived to show the similar structure between Solow-Swan model and the KY-Micro model. The financial gain (Y_{FK}) is included to illustrate the difference between them, although the financial gain is not utilized in all simulations. Financial gain from investment is a key factor in building wealth and should be considered crucial in understanding economic inequality.

Table 2. National economic growth model (KY-Macro), in which dY/dt is derived.

Description	Equations
National income or output (Y): $g_L, g_A = growth\ rates\ of\ L, and\ A$	$Y = K^{c_K} * L^{c_L} * A^{c_A}$ $\frac{dY}{dt} = (c_A * g_A + c_K * g_K + c_L * g_L) * Y$ $c_K = 0.5, c_L = 0.3, c_A = 0.2$ $c_K + c_L + c_A = 1$
Capital (K):	$\frac{dK}{dt} = s * Y - \delta * K$ $s = saving\ rate = 0.1$ $\delta = capital\ depreciation\ rate = 0.0$
Labor (L):	$\frac{dL}{dt} = g_L * L,$ $g_L = 0.05$, $L(0) = 100$
Productivity (A):	$\frac{dA}{dt} = g_A * A,$ $g_A = 0.05, A(0) = 100$
$g_Y = national\ output\ growth\ rate$	$g_Y = \frac{\frac{dY}{dt}}{Y} = c_A * g_A + c_K * g_K + c_L * g_L$
$g_K = national\ capital\ growth\ rate$ (Note Piketty used r)	$g_K = \frac{\frac{dK}{dt}}{K} = \frac{s * Y - \delta * K}{K} = \frac{s * Y}{K} - \delta = \frac{s}{\beta} - \delta$
$\alpha = Capital\ income\text{-}output\ ratio$	$\alpha = \frac{g_K * K}{Y} = \frac{K * \frac{\partial Y}{\partial K}}{Y} = r * \beta$
$\beta = Capital\text{-}Income\ ratio$	$\beta = K/Y,$ (years)
$k = K$ per capita, $y = Y$ per capita	$k = K/L, \quad y = Y/L$ $k_2 = K/(A * L), \quad y_2 = Y/(A * L)$

Derivation of dY/dt

The Solow-Swan model treated the Y as a flow and thus its derivative, dY/dt, is not derived. We derived the dY/dt to show the similarity between the KY-Micro model (Figure 1) and the Solow-Swan models (Figure 22). In contrast, the dY/dt is referred to as a flow variable while Y is called a stock variable in System Dynamics. A stock variable has always the form of $Y(t+dt) = Y(t) + (inflow - outflow) * dt$, which is equivalent to its derivative, $dY/dt = (Y(t+dt) - Y(t))/dt$.

Let $Y_t = K_t^{c_K} * L_t^{c_L} * A_t^{c_A}$, then (we removed the *t* in the equation for simpler notation)

$$\frac{dY}{dt} = c_A A^{c_A - 1} K^{c_K} L^{c_L} A' + c_K A^{c_A} K^{c_K - 1} L^{c_L} K' + c_L A^{c_A} K^{c_K} L^{c_L - 1} L'$$

$$= c_A \frac{A^{c_A}}{A} K^{c_K} L^{c_L} A' + c_K A^{c_A} \frac{K^{c_K}}{K} L^{c_L} K' + c_L A^{c_A} K^{c_K} \frac{L^{c_L}}{L} L'$$

$$= c_A \frac{A'}{A} A^{c_A} K^{c_K} L^{c_L} + c_K \frac{K'}{K} A^{c_A} K^{c_K} L^{c_L} + c_L A^{c_A} K^{c_K} L^{c_L} \frac{L'}{L}$$

$$= c_A\, g_A\, A^{c_A}\, K^{c_K}\, L^{c_L} + c_K\, g_K\, A^{c_A}\, K^{c_K}\, L^{c_L} + c_L\, g_L\, A^{c_A} K^{c_K}\, L^{c_L}$$

$$= (c_A\, g_A + c_K\, g_K + c_L\, g_L)Y = g_Y\, Y, \;\; where\ \frac{\dot{A}}{A} = g_A, \;\; \frac{\dot{K}}{K} = g_K, \;\; \frac{\dot{L}}{L} = g_L$$

In summary, the dY/dt is equivalent to its production function multiplied by the product of growth rates of *K*, *L*, and *A* and their corresponding power coefficients. The g_Y is the sum of the product of power coefficients of the factors and its growth rates. If g_L, g_A, and, g_K are positive as well as $c_A, c_K,\ and\ c_L$, the value of *Y* will continue to increase indefinitely. The negative values of c_A, c_K and c_L indicate that as *K*, *A*, and *L* are spent, the *Y* is destroyed, which is not a realistic scenario. Historically, g_L, g_A, and, g_K have been positive, thus, if $s * Y > \delta * K$, the value of *K* continues to increase indefinitely.

Case 1: base run

The first case is a base run, in which the initial values of *K*, *L*, *A*, and parameters are intentionally set so that $K(t) = Y(t) = L(t) = A(t),\ k(t) = y(t) = 1, B = K/Y = \beta = k/y = s/g_Y = 1$ and the α and the β are constant; $K(0) = L(0) = A(0) = 100$; $c_K(= 0.3) +$

$c_L(=0.5) + c_A(=0.2) = 1$, and $s = g_L = g_A = 5\%$. These settings will be used to identify the parameters that cause economic inequality. As all three initial values of *K*, *L*, and *A* are the same, and g_L and g_A are the same, the following observations can be made. It is noteworthy that even though *k* and *y* are constant, *K* and *Y* continue to increase exponentially (Figure 23).

- *K*, *Y*, and Y_K grow exponentially and *K* = *Y*. $k = y = constant = 1$.
- $g_K = g_Y = constant = 5\%$. $B = K/Y = \beta = k/y = s/g_Y = constant$.

Case 2: s is increased $(5\% \rightarrow 10\%) > g_L(5\%) = g_A(5\%)$

- (1) *K*, *Y*, and Y_K grow exponentially, (2) *K* becomes larger than *Y*, and (3) *k* becomes larger than *y* as time goes by (Figure 24) The gap between *K* and *Y* will get larger and larger.
- *k* and *y* increase initially and then reach steady-state (Figure 25). Note that even though the *k* and *y* reach steady state, the *K* and *Y* continue to increase and $K \gg Y$.
- β approaches s/g_Y and reach a steady-state as Piketty claimed (Figure 26).
- $g_K > g_Y > g_L = g_A$ and reach to steady-state of the minimum of g_L and g_A (Figure 27)

Case 3: s is increased $(5\% \rightarrow 10\%) > g_L(5\%) > g_A(2.5\%)$

- $K > Y$ and the gap between them continues to increase (Figure 28)
- The *y* and *k* increase initially and then start declining. Even though the *k* and *y* decline, the *K* and *Y* continue to increase exponentially. The *y* (e.g., year 13) declines before *k* declines (e.g., year 45) (Figure 29)
- $B = K/Y = \beta = k/y$ approaches s/g_Y as Piketty claimed (Figure 30) and they reach a steady-state. $\alpha = Y_k/Y = (g_K * K)/K$ remains constant (not shown).
- Initially, $g_K > g_Y$ and then, $g_L > g_K > g_Y > g_A$ at the steady state. (Figure 31)

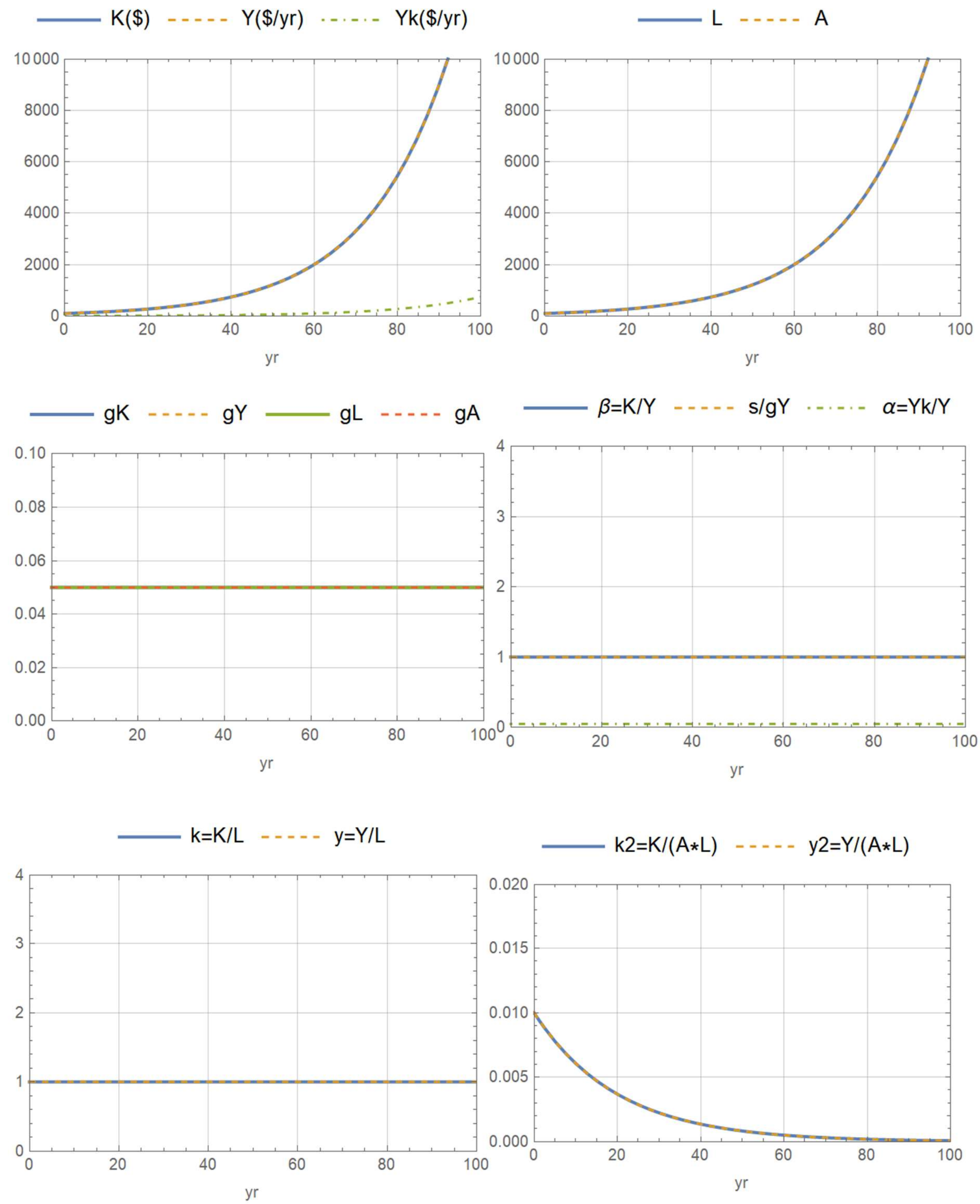

Figure 23. Base run (Case 1) where $K = Y = L = A$ and $g_L = g_A = g_K = g_Y = 5\%$. All parameter values are intentionally set to be in steady-states to analyze the effects of individual parameters. The K, Y, L, A show unlimited exponential growth with $k = y = 1$, $\beta = \alpha$, and the $k_2 = y_2$ approaching zero.

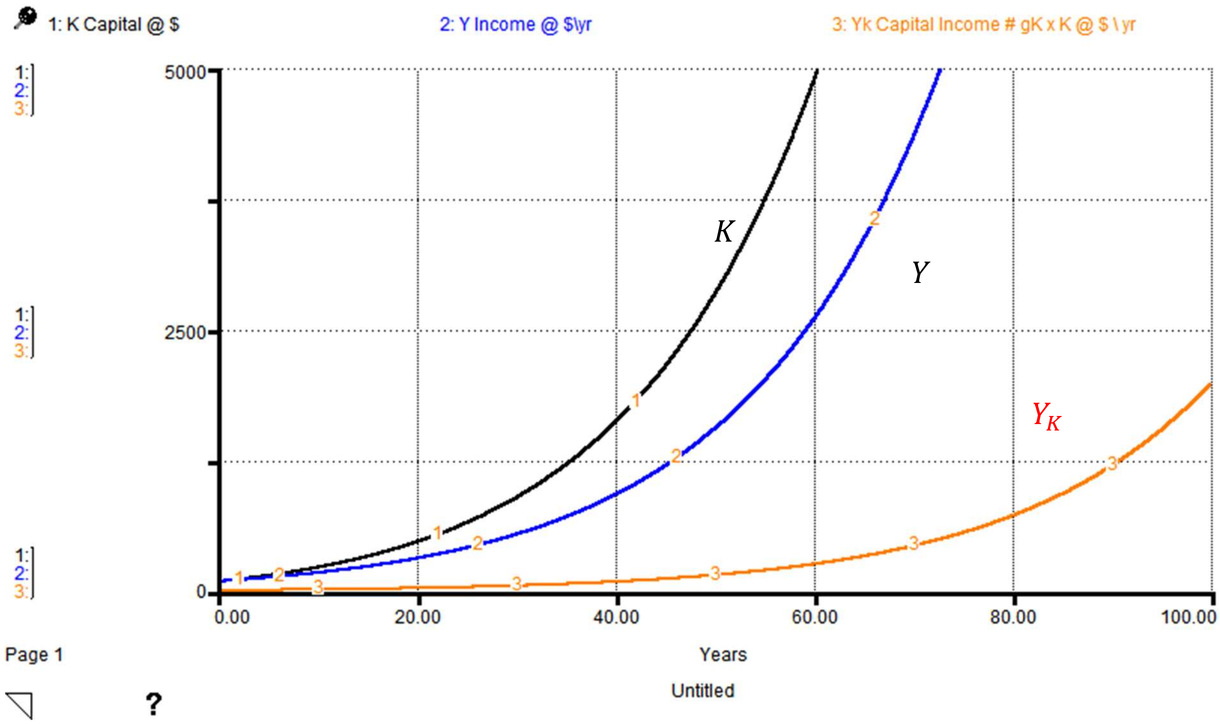

Figure 24. Case 2. If the s (10%) $> g_L(5\%) = g_A(5\%)$ then, $K \gg Y$ and the gap between them grows larger and larger.

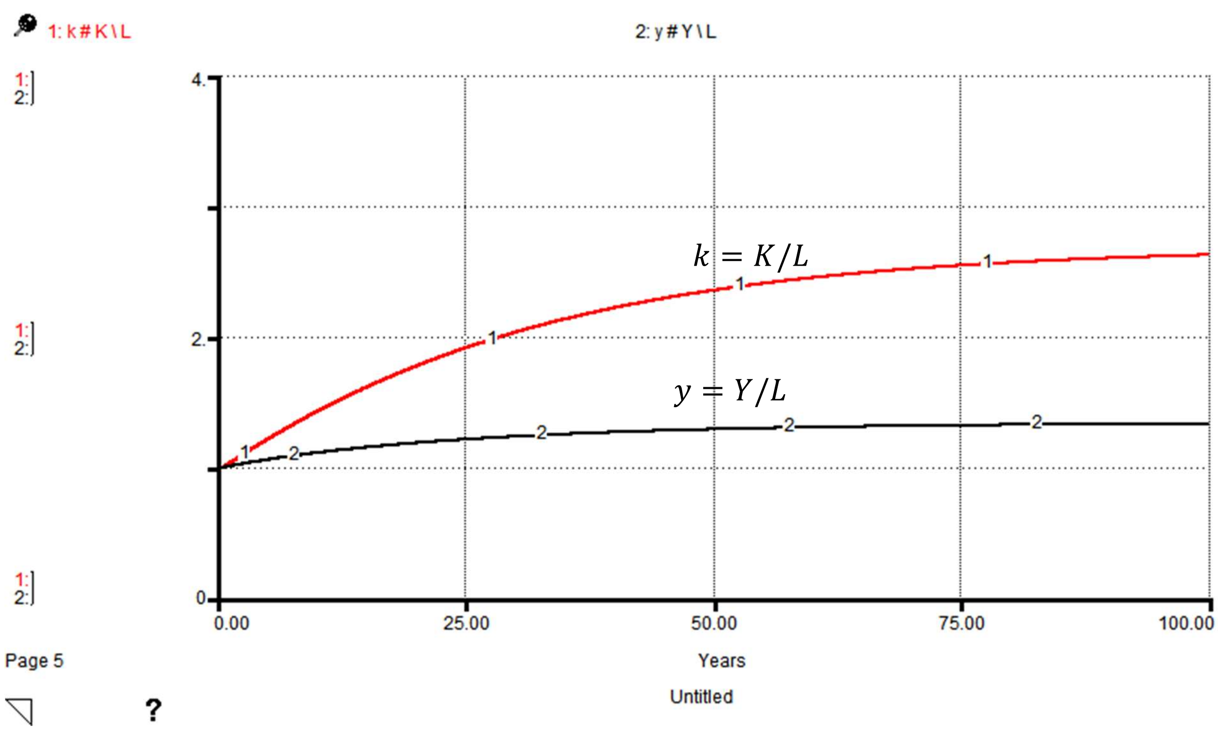

Figure 25. Case 2. The k and y increase initially but reach to steady-state, obscuring the fact that $K \gg Y$ and they continue to grow exponentially (see Figure 24).

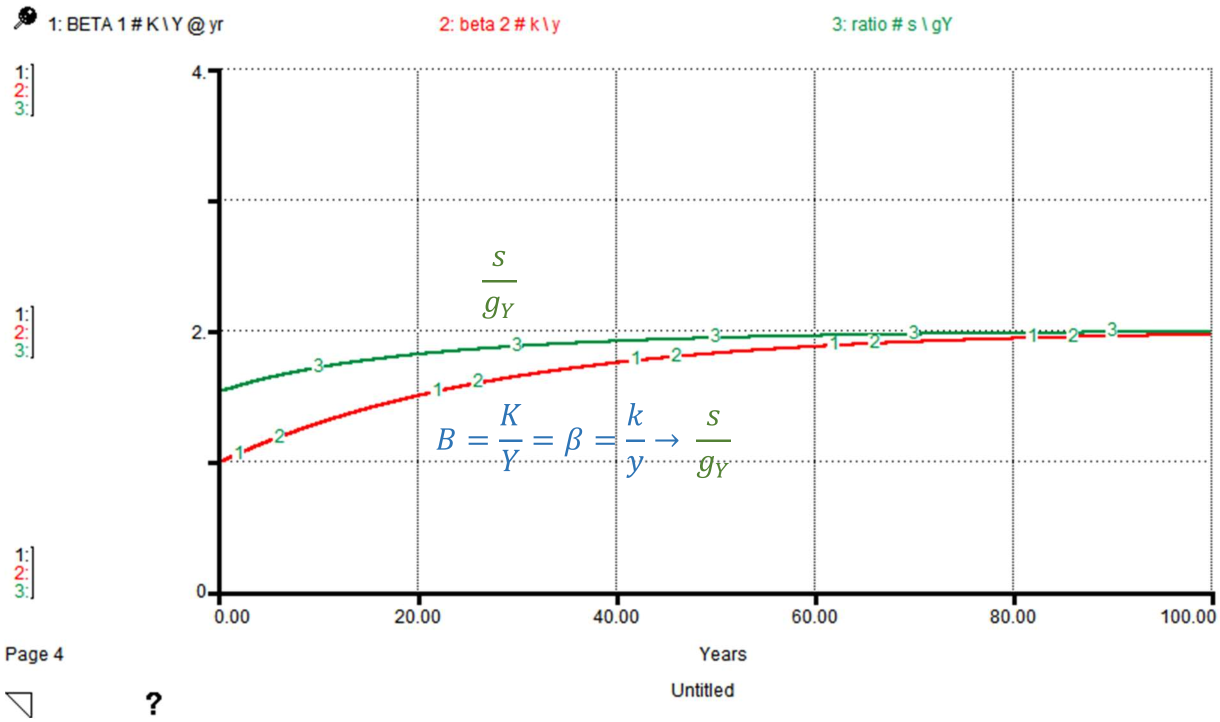

Figure 26. Case 2. The β approaches the s/g_Y, validating Piketty's claim ($B = K/Y, \beta = k/y$).

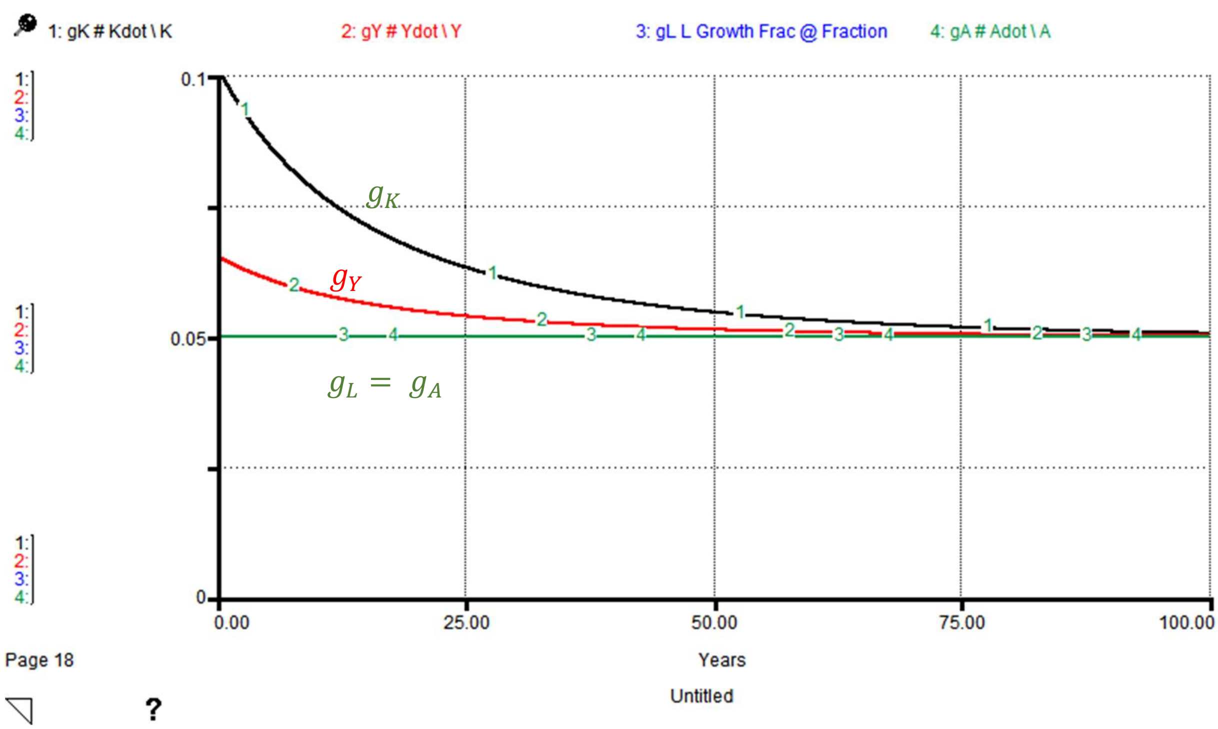

Figure 27. Case 2. The $g_K > g_Y > g_L = g_A$ and they approach the minimum of g_L or g_A.

Case 4: $\mathbf{s}$ is increased ($\mathbf{5\%} \rightarrow \mathbf{10\%}$) $>$ $\mathbf{g_A}(\mathbf{5\%})$ $>$ $\mathbf{g_L}(\mathbf{2.5\%})$

- $K \gg Y$ as time goes by and the gap between them continues to increase (Figure 33)
- k and y continue to increase ($k > y$) (Figure 34).
- The β approaches s/g_Y as Piketty claimed (Figure 35). $\alpha = (g_K * K)/K$, remains constant.
- Initially, $g_K > g_Y$ and then, $g_A > g_K \geq g_Y > g_L$ at steady state.

Summary of *KY*-Macro model

Our simulation results indicate that economic inequality is an inescapable structure, in which $K \gg Y$ over time even though k and y decline. The Y increases and thus people will be more affluent, however, the K grows much faster than the Y. Thus, the gap between people with K and without K will get larger and larger. If $s > g_L > g_A$, then $K \gg Y$ and they continue to increase. The k and y decrease but the y decrease earlier than the k decrease. If $s > (g_A < g_L)$, then $K \gg Y$ and they continue to increase. The k and y continue to increase. If $s < \max(g_L, g_A)$, then $K \ll Y$ as $t \rightarrow \infty$. If $g_L > g_A$, then k and y decrease to zero. If $g_L < g_A$, then k and y decrease first and then continue to increase. β approaches s/g_Y. They increase with diminishing rates. $g_A > g_L$ is crucial in maintaining both k and the y.

Constant principal and interest payments (CPIP)

Globalization has led to the free movement of financial resources across borders, but the movement of people is often restricted due to factors such as nationality and laws. This can have an impact on the accumulation of wealth through homeownership, as frequent relocations can hinder the ability to build equity. For example, in the US between 2001 and 2011, half of single-family buyers stayed in their homes for 6 to 9 years (Evangelou, 2020).

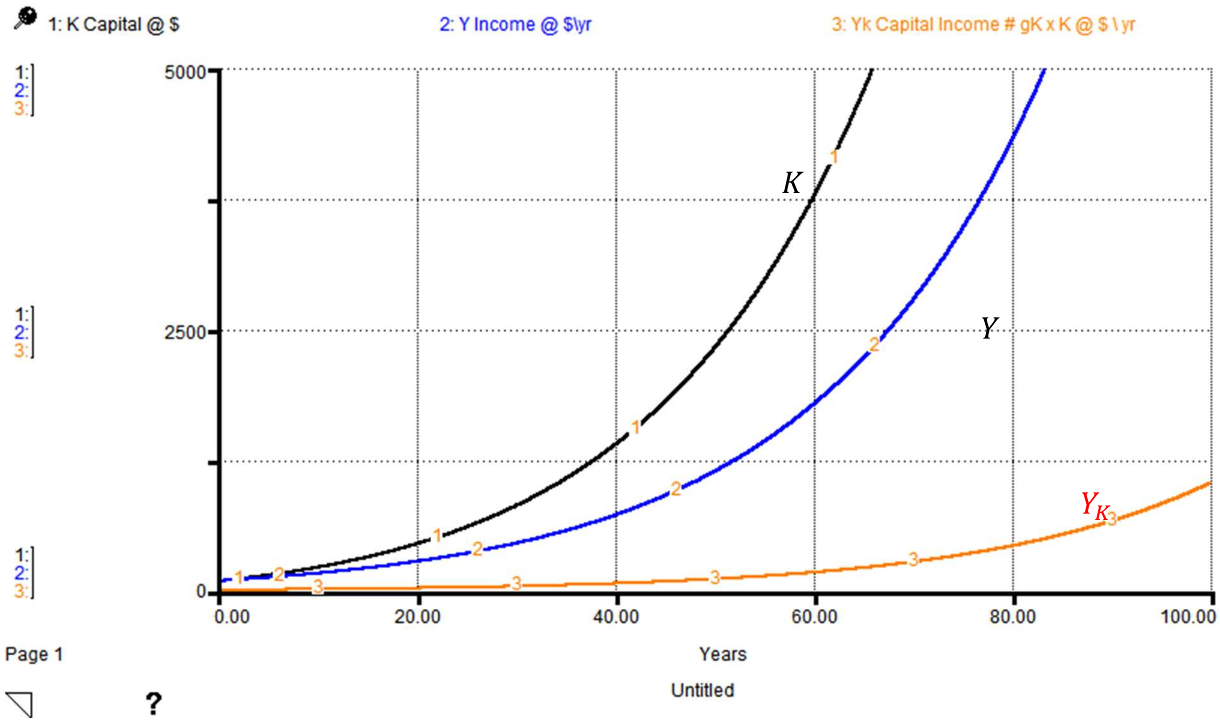

Figure 28. Case 3, in which s (10%) $> g_L(5\%) > g_A(2.5\%)$. *K and Y continue to grow exponentially,* $K \gg Y$*, and the gap gets larger.*

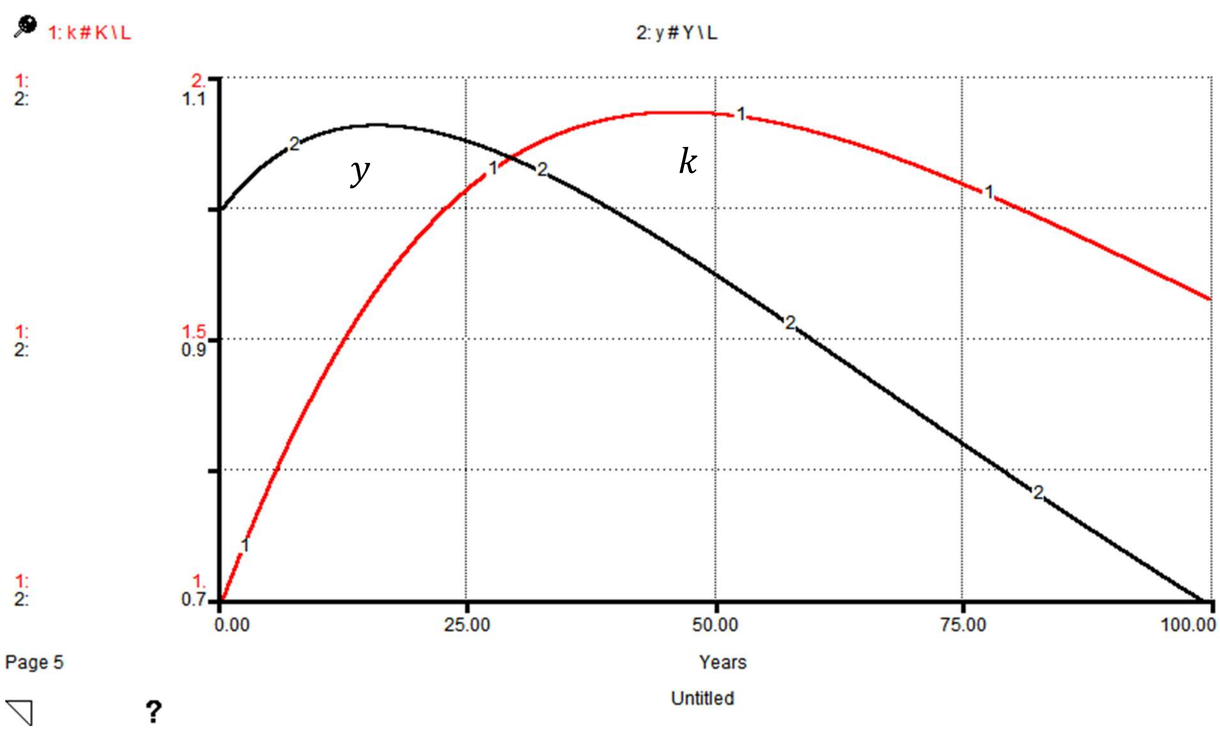

Figure 29. Case 3, in which s (10%) $> g_L(5\%) > g_A(2.5\%)$. *The y starts decreasing always earlier than k (year 15 versus year 45). Note that K and Y continue to increase exponentially (see Figure 28).*

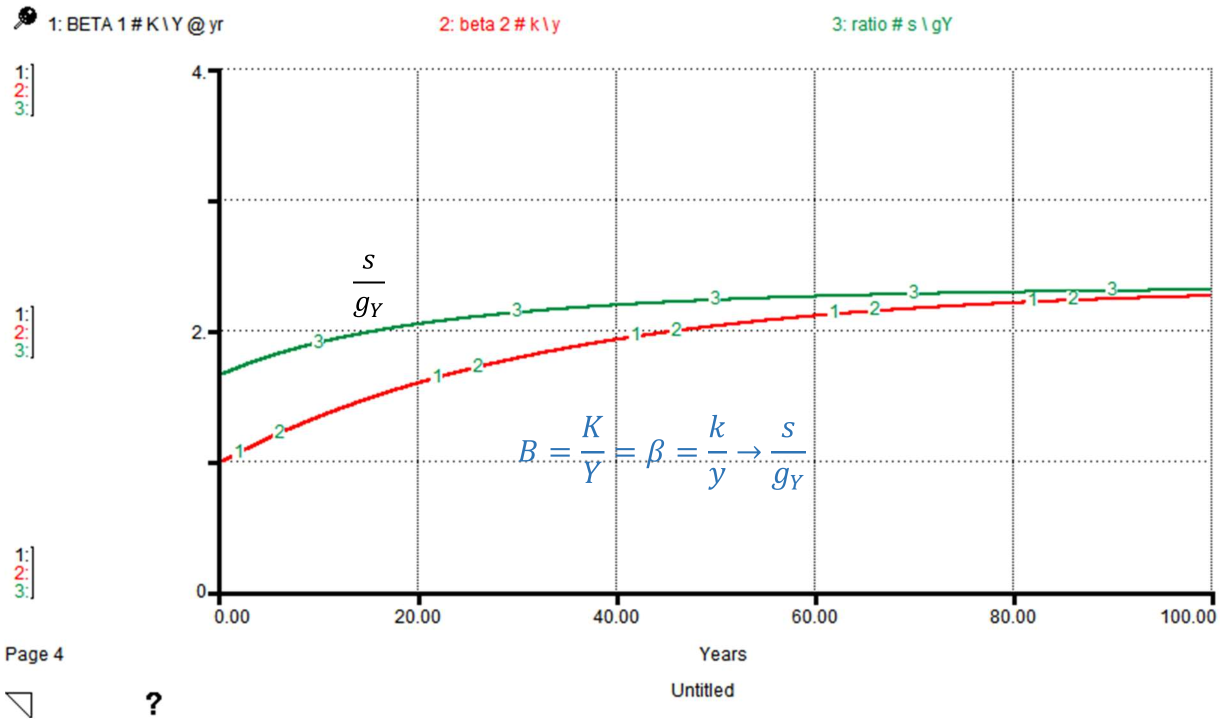

Figure 30. Case 3, in which s (10%) $> g_L(5\%) > g_A(2.5\%)$. *The* β *approaches the* s/g_Y, *validating the Piketty's claim that* $\beta = K/Y \to s/g$.

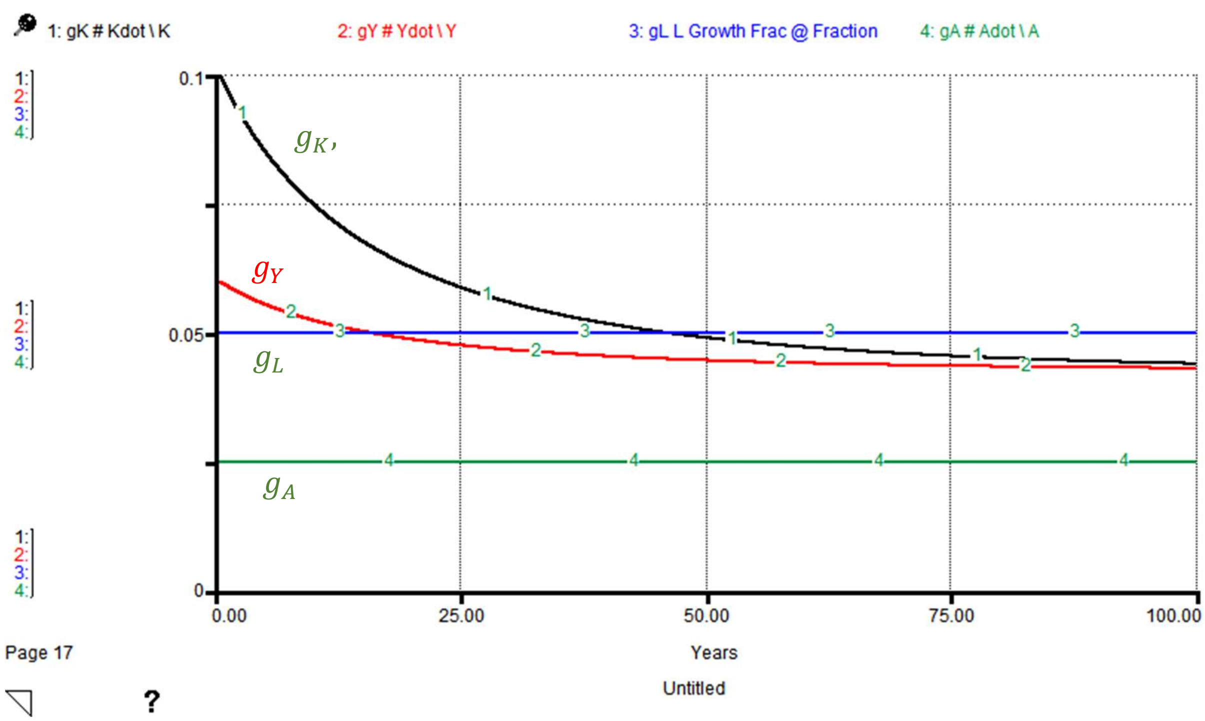

Figure 31. Case 3, in which s (10%) $> g_L(5\%) > g_A(2.5\%)$. *The* g_K *and* g_Y *approach steady state and* $g_L > g_K > g_Y > g_A$.

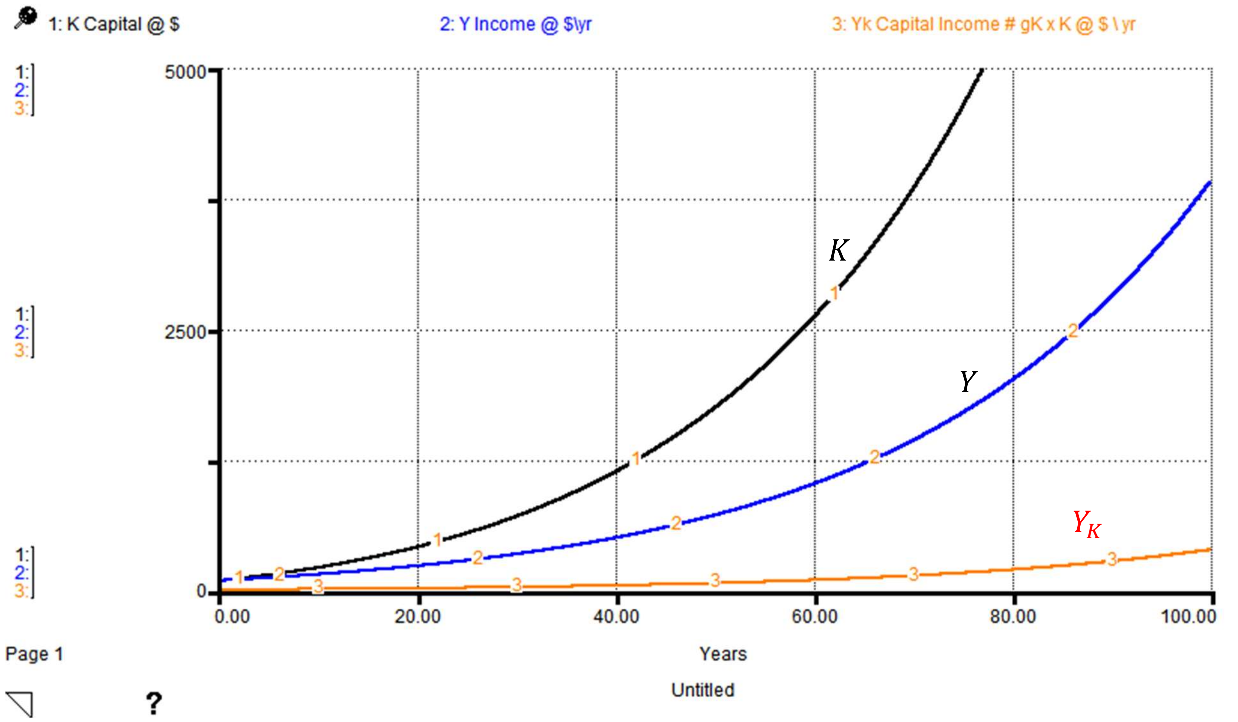

Figure 32. Case 4, in which s (10%) > $g_A(5\%) > g_L(2.5\%)$. The K and Y continue to grow exponentially, $K \gg Y$, and the gap between them gets larger.

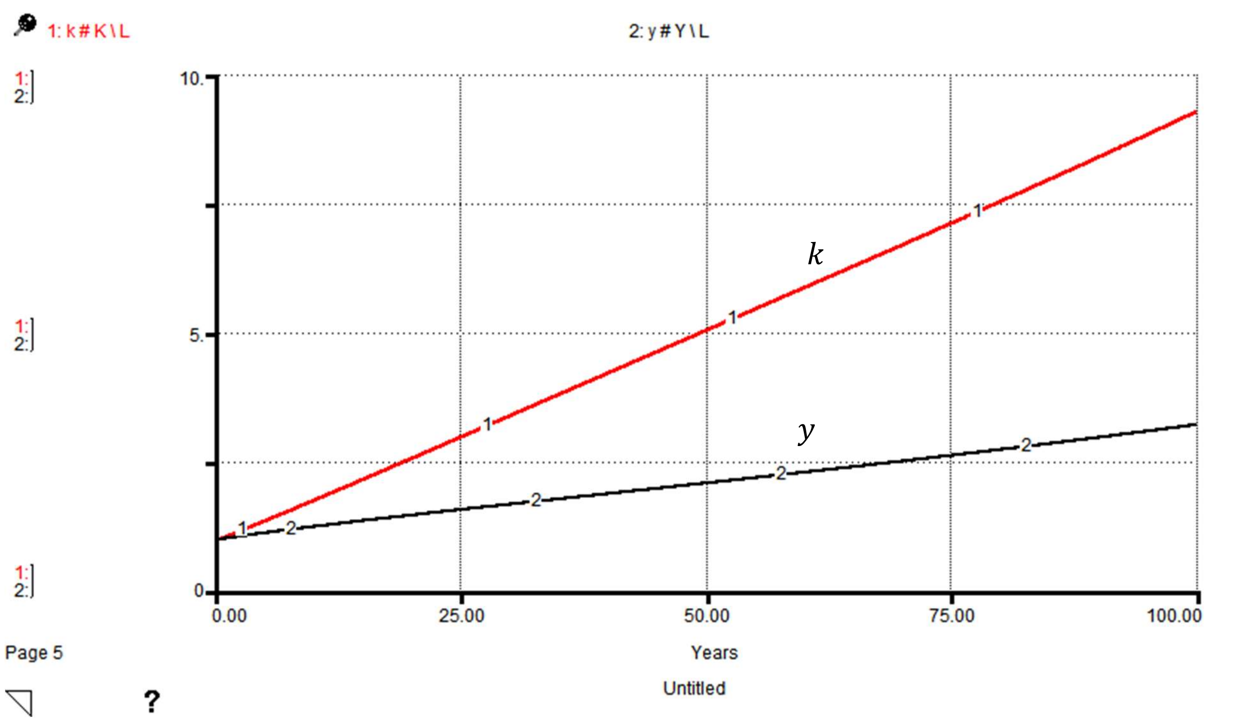

Figure 33. Case 4, in which s (10%) > $g_A(5\%) > g_L(2.5\%)$. The k and y continue to grow linearly, k > y, and the gap between them gets larger.

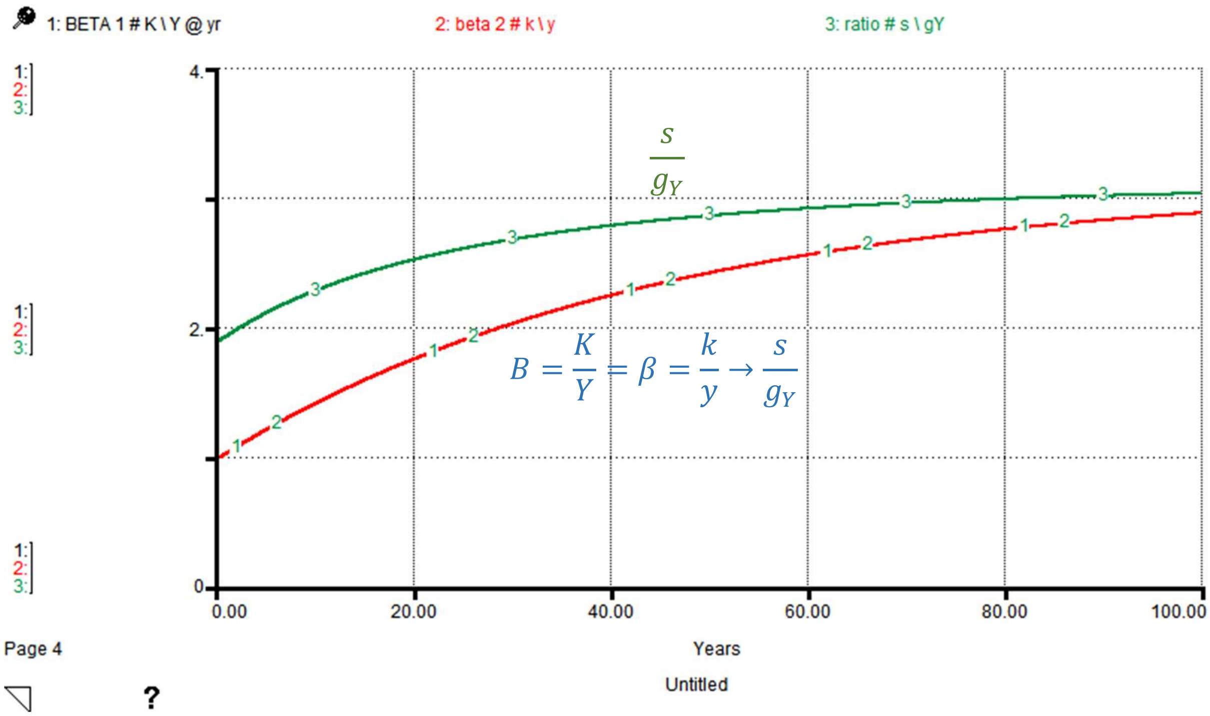

Figure 34. Case 4, in which s (10%) $> g_A(5\%) > g_L(2.5\%)$*. The* β *approaches the* s/g_Y*, validating the Piketty's claim that* $\beta = K/Y \rightarrow s/g$*.*

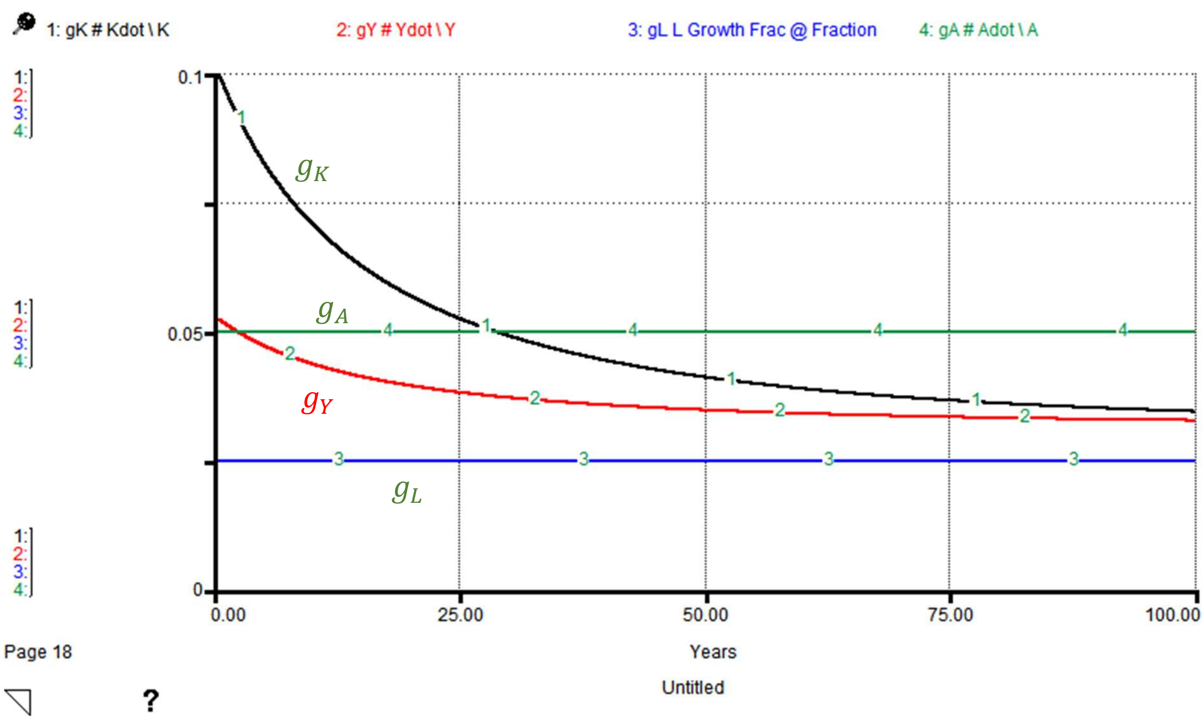

Figure 35. Case 4, in which s (10%) $> g_A(5\%) > g_L(2.5\%)$*. The* g_K *and* g_Y *approach steady state where* $g_A > g_K > g_Y > g_L$*.*

When considering a 30-year mortgage of $300K with an annual compound interest rate of 5%, most of the monthly payment goes towards interest in the early years, with only a small portion reducing the principal. Consequently, it takes approximately 21 years, or 70% of the mortgage term, to pay off just 50% of the principal. For example, a 30-year mortgage of $300K at a 5% annual interest rate results in a monthly payment of $1610. In the first month, this payment allocates only $381 towards the principal and $1,249 towards interest. Over 20 years, the borrower would have paid down $150,000 of the principal while paying $239,000 in interest. This amortization pattern highlights the slow initial progress in building equity under current mortgage structures.

We propose a new mortgage system called Constant Principal and Interest Payment (CPIP). This system ensures that constant amounts are deducted from both the principal and interest portions of the loan. Borrowers will make a fixed monthly payment of $1,610, with $833 allocated to principal repayment ($300,000/360 months) and $777 to interest ($1,610 - $833), over a 30-year term. Under CPIP, borrowers will pay the same monthly payment of $1610/month as in the current mortgage system but the CPIP pays down the constant amount to principal and interest ($300K/360 month = $833/month) and $777/month as interest ($1610-$833=777$/month) with a 30-year term. In the end, borrowers will pay the same total amount in interest ($266,000) and principal ($300,000) as in the current mortgage system. However, they will accumulate equity at a faster rate. After 10 years, homeowners will have built $100K in equity (with a remaining principal of $200K) under CPIP, compared to just $56K in equity (with a remaining principal of $244K) under the current mortgage system (as illustrated in Table 3, Figure 36, Figure 37, Figure 38,Figure 39). Moreover, the CPIP model can be applied to other forms of debt, such as credit cards, offering similar benefits in equity accumulation and repayment structure.

- Monthly principal paid ($/m) = Monthly mortgage payments ($/m) – (initial amount of principal / (12 m/year * number of years)
- Monthly interest paid ($/m) = Monthly mortgage payments ($/m) – Monthly principal paid ($/m)

Table 3. An example for the comparison between CI and CPPI

	Compound Interest (CI)	Constant Principal and Interest Payments (CPIP)
Principal, term, & APR	$300,000, 30-year mortgage, 5%	
Monthly payment	1,610 ($/m)	
Monthly principal payment	P&I are computed every month as a new mortgage is initiated and they vary over time.	= Loan amount /number of months e.g., = $300K/(12 m/yr*30 yr) = 833$/m
Monthly interest payment		= monthly payment – monthly principal payment e.g., = $1,610 - $833 = 777$/m
Total interests paid in 30 years	$279,720	$279,720
Total principal paid in 30 years	$300,000	$300,000
Total amount paid in 30 years	$579,720	$579,720

Summary and discussion

Economic inequality consists of many parts; (1) income inequality, (2) wealth inequality, and (3) capital income inequality. The key insight from these analyses is the importance of accumulating *K* that perpetuates inequality. We call the inevitable structure as *K* with *r*. The poor do not get poorer but the rich get richer much faster. The rich own most of the wealth and pay most taxes over time. Income tax serves as an effective tool for reducing inequality by limiting the amount of savings that the wealthy can convert into capital. Similarly, capital tax helps mitigate wealth inequality by disrupting the reinforcing loop of income leading to savings, which then leads to capital, capital income, and further capital accumulation.

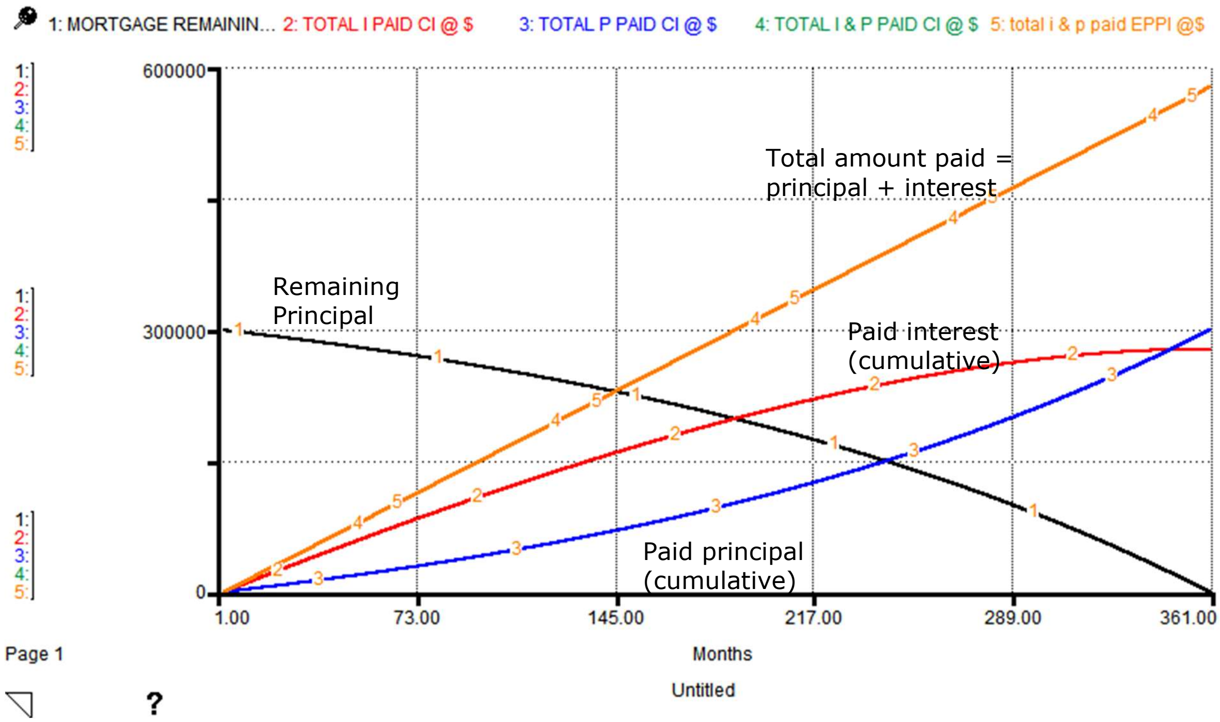

Figure 36. A 30-year mortgage with 5% compound interest (CI), illustrating the breakdown of principal, interest, and total amount paid. It takes 21 years to pay down 50% of the principal.

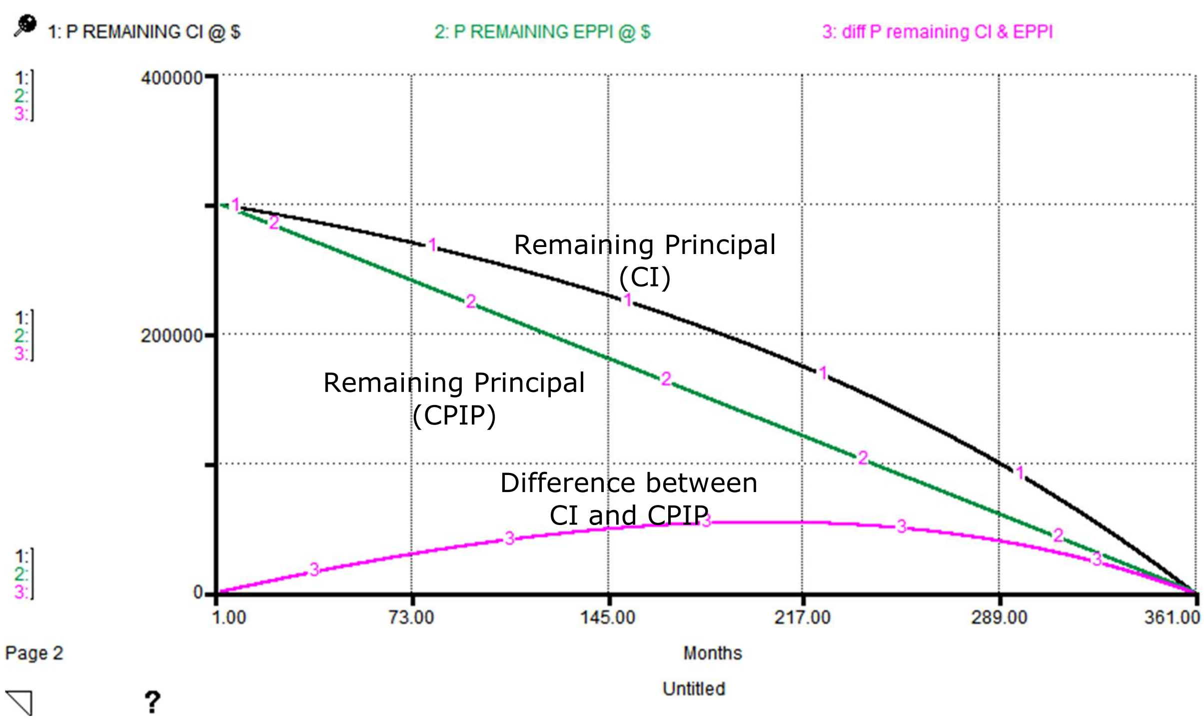

Figure 37. Remaining principal in CPIP and CI. Borrowers using CPIP have less debt to pay than CI, despite making the same monthly and total payments.

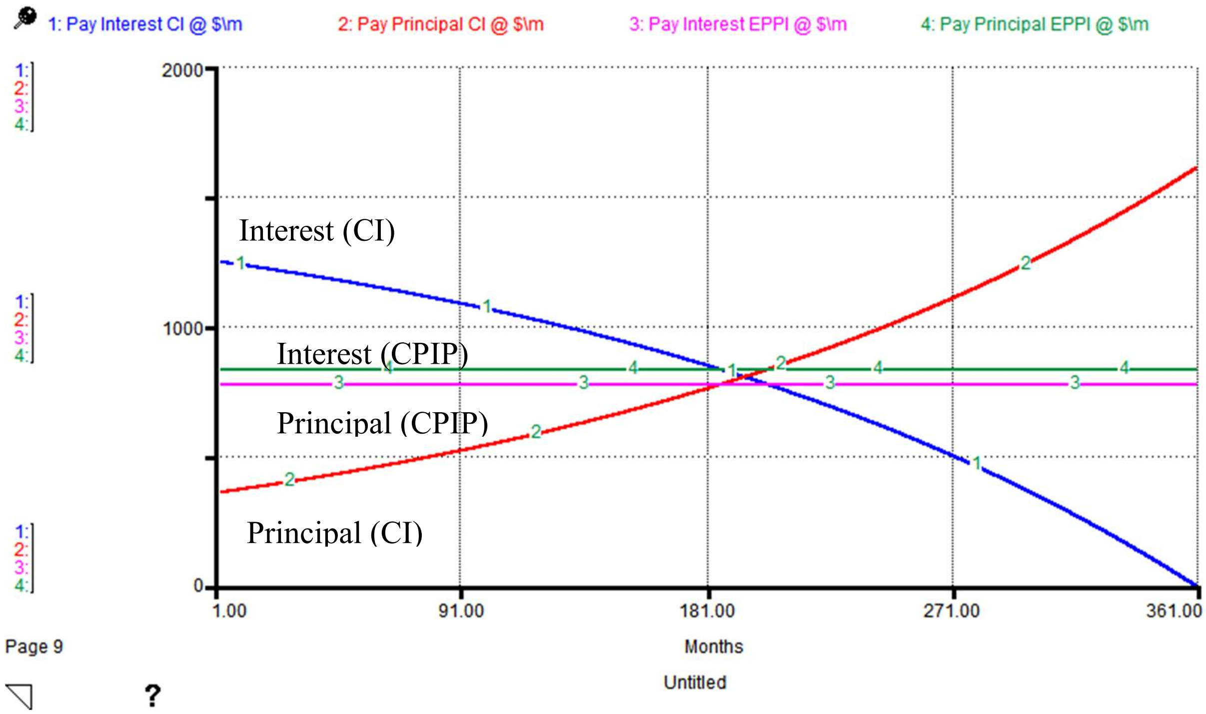

Figure 38. Comparison between CI and CPIP for a 30-year term mortgage with a 5% interest. CI results in more interest paid until 194 months. Lenders receive the same monthly and total amount.

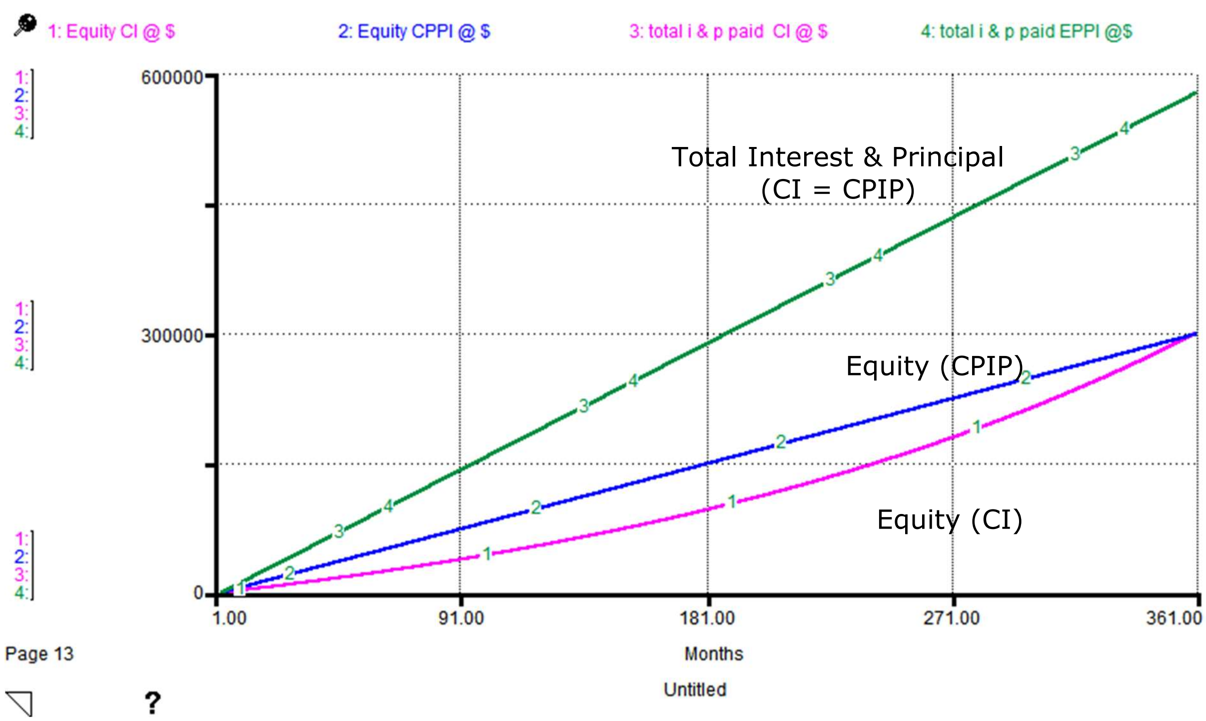

Figure 39. Comparison of total amount paid and equity between CI and CPIP. Lenders receive the same amount in both scenarios, but borrowers will have more equity in CPIP.

The current definition of GDP does not account for financial gains from stock investments. Given that the size of the financial stock market in countries like the US far exceeds the national output, it is crucial to include financial income as part of the national income to fully comprehend economic inequality.

The Solow-Swan model provides an analysis of national terms of k and y. However, the model's focus on k and y unintentionally masks the fact that, over time, K will significantly exceed Y. This leads to a widening gap between people and nation with and without K. Our modified version of the Solow-Swan model, which we refer to as the *KY-Macro*, demonstrates that if the saving rate surpasses the rates of population or productivity growth rates, K will greatly exceed Y over time. If the $g_L > g_A$, both k and the y increase initially and then decrease, however, y starts to decrease before k, even though K and Y continue to increase. If $g_A > g_L$ then both k and y continue to increase. In both cases, we found that the $\beta \to s/g$ as suggested by Piketty.

To mitigate the inequality, we propose a new mortgage system called the constant principal and interest payments (CPIP). This system aims to balance between compound and simple interest rates. In the CPIP system, the principal of the loan will be reduced linearly over time. The difference between the monthly payment and the linearly decreasing principal is paid as interest. The borrower will make the same monthly payment throughout the loan term as the compound interest. In the end, borrowers pay the same total amount as interest and principal in total as they would under the current mortgage system. However, the CPIP system has the added benefit of allowing borrowers to accumulate equity at a slightly faster rate. This approach could potentially help mitigate some aspects of economic inequality.

Declarations

- Author Note. The author received no financial support for this article's research, authorship, and publication.
- Authors' contributions: Sangdon Lee developed the SD models, simulated the results, and wrote this research paper
- Availability of data and materials: all models developed using Stellar and Mathematica

References

Acemoglu, D. (2009). *Introduction to Modern Economic Growth*. Princeton University Press.

Evangelou, N. (2020), How long do homeowners stay in their homes? National association of realtorshttps://www.nar.realtor/blogs/economists-outlook/how-long-do-homeowners-stay-in-their-homes.

Jonathan D., Prakash *L*, Andrew B. (2019), *Confronting inequality*, Columbia University Press.

Krueger, *A*. (1974). The Political Economy of the Rent-Seeking Society. *American Economic Review*, 64 (3), 291-303.

Mislinski, J. (2020). "Market Cap to GDP: An Updated Look at the Buffett Valuation Indicator". www.advisorperspectives.com.

Oxfam (2020). The world's billionaires have more wealth than 4.6 billion people. https://www.oxfam.org/en/press-releases/worlds-billionaires-have-more-wealth-46-billion-people retrieved on July 28, 2020.

Piketty, Tomas. (2013). *Capital in the Twenty-First Century*. Cambridge Massachusetts: The Belknap Press of Harvard University Press.

Griffin, R. C., Montgomery, J. M., and Rister, M. E. (1987). Selecting functional form in production function analysis, *Western Journal of Agricultural Economics*, 12 (2); 216-227.

Romer, D. (2011). Advanced Macroeconomics (Fourth ed.). New York: McGraw-Hill. pp. 101–149.

Solow, R. M. (1956). *A* contribution to the theory of economic growth. *Quarterly Journal of Economics*. 70 (1): 65–94.

Stiglitz, J. E. (2015). *The Price of Inequality: How Today's Divided Society Endangers Our Future*. New York: W.W. Norton & Co.

Swan, T. W. (1956). Economic growth and capital accumulation. Economic Record. 32 (2): 334–361.