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Abstract

I start with income and wealth inequality data from the Congressional Budget Office (CBO) and Thomas Piketty, and propose approaches taken from science (for example, behavioral evolution theory,) that might be useful in explaining the data and forecasting future economic events. Using a modified production function developed by Robert Solow, I also explore redistributive effects of income when biological restrictions lead to minimum expenditure requirements and satiation conditions. I conclude that redistributing income from the wealthy to the poor can have counter-cyclical effects in recessions. Moreover, redistribution in the form of human capital can have particularly large positive economic growth effects. Finally, I explain how financial crisis may lead to large economic downturns by proposing a model where productive capital formation is dependent on debt financing.

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1 Introduction

My purpose is to communicate a fresh way at looking at macroeconomics. A view that integrates techniques from traditional economics, science and what Thomas Piketty calls political economy. Although I use data and conclusions from the works of Piketty, I do not agree with his assessment that economics needs to become less of a science. See Piketty (2014). I hope to bring insights to macroeconomics that I have gained from being a chemical engineer specializing in microbiology, an economist and lawyer.

The Ideal Gas Law economy is a metaphor for New Classical Macroeconomic models that assume hyper-rational agents in a market clearing economy. I go beyond New Classical models with further science applications to economics. In particular, I claim that Natural Selection favored individuals that have fear to quickly avoid dangerous situations. For example, this fear can detonate a chain reaction of bank runs and failure, which in turn causes the fusion of debt defaults. The aggregation of debt defaults causes the economy collapse. This is analogous to a hydrogen bomb where a fission bomb denotes the fusion bomb, causing much destruction.

I also ask, what does the data tell us? According to standard neoclassical economic theory, wealth shares of different income groups should converge to different levels. Thus, in the long run, the degree of wealth inequality should remain constant. This hypothesis should occur because mathematically capital accumulation follows an infinite series that converges when capital depreciates. If this hypothesis is true, then what is causing the degree of inequality between income groups in the United States and Europe to diverge? Will attempts to redistribute wealth increase or decrease economic growth? Can a redistribution of income and wealth have counter-cyclical and thus, smooth out business cycles or increase the recovery pace of economies emerging out of deep economic downturns. I conclude that human features that are a product of human evolution can cause counter-cyclical and pro-growth economic effects. This is particularly true when resources are used to build up human capital. In this research, human capital can just mean education and job training, but in other contexts, it can also mean health care and other personal investments that lead worker's to become more productive.

The price of greater equality and human capital accumulation is a reduction in capital formation. However, according to Piketty, much capital is not productive. For example, treasures stored in a vault does little to increase GDP. Thus, redistribution effects may increase economic output if much of the capital stock is nonproductive.

The organization of this paper is as follows: I will provide the gas and fluid law (or balloon economy) analogy in section 2. The development of Dynamic Stochastic Equilibrium DSGE models and the criticisms of these models by econophysicists are discussed in sections 3 and 4. In section 5, I will propose a general procedure in attacking macroeconomic problems. In section 6, I set up a macroeconomic growth model that uses concepts from the other sciences. In section 7, I report results of simulations using the model with discontinuities developed in sections 5 and 6. In section 8, I modify the model to analyze the financial collapse of 2008 using a hydrogen bomb analogy, and draw up conclusions and suggestions for future research in section 9.

2 The Balloon Economy Analogy

In the nineteenth century, chemists thought of gasses of being composed of individual molecules randomly moving in a container. By assuming that these molecules are of infinitesimal size, and are relatively far apart such that they do not interact with each other, they were able to derive the famous Ideal Gas Law:

$$PV = nRT \tag{1}$$

where P is pressure, V is volume, n is the number of moles, which is proportional to a number of molecules, R is the proportionality constant and T is temperature. See e.g. Dickerson et al. (1979). Think of blowing into a balloon. The volume of the balloon grows as you blow more air into it. This represents the value of n increasing. You can also grow the balloon by raising the temperature of the air.

The Ideal Gas Law is analogous to the first New Classical models, including early Real Business Cycle models. In these early models, the macro economy was populated by isolated agents. These isolated agents optimized their utility subject to their resource constraint (From the perspective of a scientist or engineer, a mass or energy balance). The Robinson Crusoe resource constraints were determined by how many hours they worked and how much capital they employed for production. Macroeconomic behavior could then be described by the sum of all individual behavior in the economy.

In many ways, the Ideal Gas Law equation is analogous to the neoclassical production function:

$$f(K,L) = Y \tag{2}$$

where f represents a concave production function that is increasing in aggregate capital K and aggregate labor hours L, and Y is aggregate output. Output is like the volume of the balloon. The more people in the economy the larger the labor force, and thus the economic balloon will grow. Rising capital stock is like increasing the temperature of the economy, causing the economic balloon to expand.

But we live in the real world. Many gasses do not obey the Ideal Gas Law. The problem is that gas molecules have size and do interact with each other. For ideal gasses the quantity PV/RT equals one for one mole of gas. Thus, the compressibility factor $z = PV/RT$ was created to measure a real gas's deviation from ideal. In reality, molecules impose attractive and repulsive forces upon each other, causing z to deviate from one. The determination of z is purely empirical and varies with temperature and pressure.

In 1873, Johannes Van der Waals also refined the ideal gas model. He allowed for molecular attractiveness and the fact that molecules take up size. I am not going into great detail of his model. But his model takes the form of $V = f(n, P, T)$.

The Van der Waals equation describes the behavior of gas at a much larger range of temperatures and pressures than the Ideal Gas Law. The Van der Waals equation sacrificed the nicety and beauty of theory for a more accurate prediction of reality. In many ways, this is analogous to economic research trends over the last couple of decades. Real Business Cycle models have been modified to include Keynesian market imperfections,. These models are called Dynamic Stochastic Equilibrium Models or DSGE models. A more radical approach is taken by a new field called Econophysics. Econophysicists use terminology from physics to describe economic phenomenon.

In this research, I start of with the basic neoclassical production function. Like the scientists in the nineteenth century, I will make modifications to what is current in macroeconomic and growth theory. Thus, I will now discuss the theories I attempt to modify.

3 Development of DSGE Models

There once was a time when macroeconomists thought that government created tides that could move ships. In many ways, they thought of macroeconomics as a mechanical science where strong external forces could move ships and individual particles. But by the late twentieth century, economists thought of people as rational beings who had free will. According to John Muth's Rational Expectation's Hypothesis, buyers and sellers in the market place do not simply extrapolate from the past when predicting future prices, but make the best decision given the information available at the time, Muth (1961). Because they were rational, they had the capacity to swim against the currents and counteract any government attempt to move their ships. Thus, government policy was ineffective.

According to these economists, rationality and market perfection meant that the economy was traveling at maximum efficiency. Because the economy was already traveling at the speed of light, there was no government policy that could make it run faster, if anything, the government could only make economic matters worse. In 1976, Lucas argued that macroeconomic models had to be derived from observed individual behavior or have a microfoundation. This was to provide certain parameters in econometric models to have structure. Without structure, these parameters could change with different government policies, rendering these models useless, Lucas (1976).

The first element of the DSGE model was to construct a microeconomics model based on a representative agent or household. A representative agent is a theoretical person who mathematically represents the average person in the economy. A macroeconomist attempts to predict what the outcome of an economic policy change will be by predicting how the representative agent reacts to the policy shift.

3.1 Real Business Cycle Model

The Real Business Cycle (RBC) model was introduced in, *Time to Build and Aggregate Fluctuations* (Kydland & Prescott, 1982). We will analyze a simple version of this model in greater detail since this will be the starting point for a model considering survivability and evolution theory discussed in section 6. RBC models starts with a resource constraint:

$$f(K,L) = Y = C + I \tag{3}$$

where f was the production function, K capital stock of the economy, L amount of labor hours in the economy, Y income or economic output, C consumption and I investment. Investment is then rewritten in terms of current and future capital stock. In RBC models there is no money in the economy because money is neutral.

Because people are forward looking and rational, economic models must be dynamic and economic participants must optimize some objective function, Kydland and Prescott (1982). In the model, current capital stock and wealth of the economy is determined by the level of capital stock in the past. Assuming no inventory build up, investment I_t during period t equals to the net increase in capital stock over the depreciated amount of capital.

$$I_t = K_{t+1} + (1 - \delta)K_t \tag{4}$$

where K_{t+1} represents the capital stock in period $t+1$, K_t is the capital stock in period t, and δ is the depreciation rate. Equation 4 implies that investment is equal to the increase in capital stock when there is no depreciation.

We can substitute equation 3 into equation 4 to get:

$$f(K_t, L_t) = C_t + K_{t+1} + (1 - \delta)K_t \tag{5}$$

In addition, households maximize their utility by choosing how much to consume in each time period, and how much leisure they want to take away from work. The concave utility function for each period takes the form of $U(C_t, L_t)$ where utility is increasing in consumption and decreasing in work (increasing in leisure). The choices households make is constrained by the resource constraint given by equation 5. In the model, the representative agent is both consumer and producer. In a sense, she is a single particle in the big box.

In RBC models, random variations or shocks in technical innovations cause business cycles. Thus, using Robert Solow's growth model, Solow (1957), they usually write their resource constraint as:

$$Af(K, L) = Y = C + I \tag{6}$$

where A represents a measure of technical change. The term A randomly fluctuates from period to period. Low values of A causes recessions and high values causes booms. Long term trends in innovations also drive economic growth when the period of explosive capital and labor growth is over. Because the production function is concave, without innovations or other factors that increase the productivity of production, economic growth eventually slows down to a near zero growth rate. In later sections, I assume that A grows at a constant rate. I then explore what happens when the returns on capital are greater than the economic growth rate $r > g$. I explore whether Piketty's conclusion that this inequality leads to increasing inequality is plausible.

The representative agent (the particle) problem in a simple RBC model can now be specified as maximize discounted utility subject to the resource constraint:

$$\sum_{i=1}^{\infty} \beta^{t-1} u(c_t, l_t) \;\; s.t. \;\; c_t + k_{t+1} + (1-\delta)k_t = A_t f(k_t, l_t) \tag{7}$$

where β is the discount factor, and lower case letter variables denotes quantities for the individual rather than for the aggregate.

Real Business Cycle theorists make one last assumption to ensure that a solution to the problem is found. They assume that in the last period of existence T, the representative agent would have just consumed all of her wealth. In other words, if the representative agent dies still possessing wealth, she would have not optimized her choices. This condition is known as the transversality condition. In an infinite horizon case, the transversality condition requires the present value of wealth to converge to zero.

The characterizations of the RBC model is well known in economic circles; thus, I will not go into further detail in its description. What is important to remember is that exogenous technology or productivity shocks drive the RBC model. When A_t rises, the economy grows, but when it falls, growth fall. But what causes a low value of A_t? Some explanations were drought, war, and pests. Other economists said sharp rises in oil prices were also to blame. But rising oil prices is often not a true technology shock, but a consequence of demand and supply in oil markets. Thus, they would have to identify an underlying shock to the oil markets to make this explanation consistent with their model. Identifying the sources of productivity shocks has been a real challenge to RBC theorists. See Mankiw (2012).

But even New Classical economists had doubts on the RBC models. Many believed that in the short run monetary policy can induce quite violent business cycles. Others felt uncomfortable with the perfect market assumptions, and the consequence that government can do nothing to increase social welfare during recessions.

3.2 New Keynesian Macroeconomics

Now days, Keynesian concepts have been incorporated into DSGE models. In these New Keynesian models, technical problems such as sticky prices and wages cause imperfect markets. These imperfect markets cause involuntary employment during recessions and gives reason why government can take action to counteract recessions or provide relief to people who suffer the effects of recession.

DSGE models as popularized by Smets and Wouters (2003, 2007) are now being used by central banks and other policy institutions. These models have grown in complexity since the early RBC days. They now include a representative household, a representative final goods producing firm, a continuum of intermediate producing good firms, and a monetary authority. Thus, the size of the economy now takes the form $Y = F(K, L, M, i)$ where M is the money supply and i is the nominal interest rate.

In this paper, I make no assumptions of whether the economy is New Classical or New Keynesian. Rather, like econophysicists, despite this new complexity, I am unsatisfied at the lack of complexity these models can analyze. In the next section, I discuss how scientists criticize this approach to macroeconomics.

4 Econophysics and Criticisms of DSGE Models

The problem with the micro foundations approach is the difficulty of analyzing complexity. Many econophysicists also criticize the general equilibrium approach of traditional economists. According to Mark Buchanan, the restriction that economic systems are always stable and trend toward equilibrium makes macroeconomics boring. When studying the weather, limiting research to clear and sunny days is not interesting. Meteorologists are interested in hurricanes and tornadoes. Even though these storms are relatively rare events, these are the events that make the news, Buchanan (2012).

According to Eugene Stanley, in order to understand economics, researchers must study the data. Economic theory is nice, but not necessary. Stanley states:

> But as you know econophysics is a little like a regular physics discipline in the sense that there is simply no theory of many things; for that matter a lot many things in physics have no theory what so ever. One of the most dramatic discoveries in physics, which happened about 25 years ago, that is high temperature super-conductivity, was made empirically. . . [N]o one ever knows why this works, Stanley (2013).

In other words, writing down a theory for complex systems will hold back advancement in the field. Sometimes, it's better just to look at the data and empirically test for what relationships that can be found. For example, the compressibility coefficient was created because it fit the data, and not from any theory. Because of this attitude, econophysics is data intensive and does not seek a grand unifying theory of macroeconomics. Rather, econophysics tends to study specific economic phenomenon. Econophysics also makes no assumptions whether individual agents are rational or even whether markets clear or not.

The Ideal Gas Law and Van der Waals equation can be derived from a branch of science called Statistical Mechanics. In Statistical Mechanics, statistical analysis of individual particles are used to derive physical laws of behavior. But for more complex systems such as fluid flow, physicists assume that mechanics dominate individual behavior. That is, the scientist does not worry how each individual molecule will behave, but how molecules will act together when obeying certain physical laws.

In economics, researchers want to stick to mathematical models where the characteristics of continuity, existence and uniqueness hold. Physicists often disregard these desires because they limit the scope of their theories and research. The real world is filled with discontinuities. For example, gasses undergo phase transitions when temperature falls to a critical point. Furthermore, in fluid mechanics, the Navier-Stokes equations are used to describe fluid flow even though existence of smooth solutions cannot be proven for three dimensional fluid flows, See e.g. Tao (2007). Fluid flow must obey the laws of conservation of mass, energy and momentum. In this research, minimum expenditure and satiation conditions are discontinuities.

Because social forces dominate individual behavior a representative agent model may not be necessary or even appropriate. Aoki and Yoshikawa (2007) argue that many macroeconomic variables such as GDP are non-self averaging.

This means that as the number of agents increase toward infinity, dispersion does not decrease, leaving the mean of aggregate variables meaningless. In this research, I break down agents into six income groups. Thus, instead of one average agent to represent all households, I use six different agents. This use of categorization should alleviate possible non-self averaging problems.

In Statistical Mechanics, if you inject molecules in a box, the molecules will randomly fly and bounce around the box. But as the number of molecules grows, a pattern emerges or a statistical equilibrium is reached. If there are no forces acting upon the particles, the Second Law of Thermodynamics states that the particles will be placed in increasing disorder. Puncture the box, the particles will eventually escape through the hole. Once the particles escape the box, they will disperse throughout the universe because entropy always increases for closed systems.

In order for particles to move in concert, such as water molecules in a river, other outside forces must be acting upon them. Thus, the individual nature of the molecule does not have to be specified. Rather, the aggregate behavior of the gas in a balloon will be determined by forces such as the temperature and pressure of the system. How far the balloon can expand before it pops depends on how big the balloon is, and the material it is made from.

What are the social forces that overwhelm a person to act like a random individual particle? Humans are herd animals that follow leaders. Humans also rely on experts or people who are the trend setters. Other social forces may include culture, social pressure and legal constraints.

In my model, individuals do have some autonomy. However, they will face extra constraints that they do not face in a DSGE or RBC economic model. As mentioned, individuals are bounded by biology and face minimum expenditure and satiation constraints. They also face legal and social constraints. For example, consistent with the CBO's findings, poor people do not directly share in the fruits of economic growth. The wealthy receives a disproportionate gain from aggregate income growth.

5 Attacking the Macroeconomic Problems

In order to determine the role that inequality plays in determining macroeconomic behavior, I look at the data and ask what phenomenon can explain patterns in the data. Then ask what laws must be obeyed? Often times the economist assumes that markets always clear or interest rates help determine equilibrium output and prices. But are these phenomenon proven to be immutable laws? Without proof, to incorporate these assumptions into an economic model, the economist must test these theories to see if they add predictive value to how the economy truly behaves. The following are the laws that I will use in my analysis.

5.1 Laws that Must be Obeyed

1. The Conservation of Mass & Energy

Conservation laws state is that in a closed system matter and energy cannot be created nor destroyed. For economists, this means that resource constraints must be obeyed. Thus, aggregate demand is $Y^d = C + G + I + NX$ where Y^d is aggregate demand or total spending, C is consumption, I is investment and NX is net exports is valid. This also means that aggregate supply models that take the form of $Y^s = Af(K,L)$, where Y^s is aggregate production or supply. However, setting these equations to be equal is only valid if it also consist of inventory. The laws of physics do not guarantee that markets clear. Notice, if inventory buildup is positive, this could mean that there is excess supply in the economy, and excess demand if inventory stock is falling. Traditional economists counter that equilibrium requires that firms hold an optimal quantity of inventory; therefore, it is impossible to argue that the economy often strays from equilibrium. Nevertheless, the difference between supply and demand will always equal inventory buildup.

2. The Second Law of Thermodynamics

The Second Law of Thermodynamics states that for a closed system entropy never decreases. This means a closed system will always tend toward increasing disorder. For the economist, this means that capital depreciates. Because of depreciation, accumulation of capital at a constant rate cannot increase economic growth at a constant or increasing rate without technical innovations. Restoring depreciated capital requires energy input.

3. Evolution and Survivability Requirements

The Second Law has profound consequences to economics. The goal of agents is to use free energy (energy that can be used for useful work) and convert it to utility gaining energy. However, the process of converting free energy to useful work produces entropy and disperses energy. Because of this law, humans are constantly in search of energy to sustain them. From this, I advocate a third law that must be obeyed in economics. That is humans need a minimal amount of resources to survive, and economic agents try to maximize their probability of short term survival. For example, agents will consume first the consumption goods that allow them to survive, and then worry about luxury goods later.

4. Satiation

Physics also tells you that when resources are limited, an individual cannot grow without bound. Thus, evolution would favor species that become satiated after eating a certain quantity of food. An environment with abundant food supply may favor large species. However, when food supply is limited, smaller sized species are more fit to survive such environments. An individual with such a large income that any additional income will not increase her calorie intake may eat more expensive food. But at some point, the individual will become satiated eating even the most expensive food. Moreover, eating too much food can makes a person lose utility by making her obese.

Of course, there other forms of consumption. One can argue that a wealthy individual can buy a movie theater and other consumptions goods that are expensive. But what we think of expensive consumption goods are actually capital goods. For example, a movie theater is a business; thus, a capital good. Moreover, antique cars, and masterpiece paintings are expensive goods where the owner may one day resale the goods for a profit. Once a person achieves satiation in consumption and human capital, he or she is free to accumulate capital at an increased pace.

5. Social and Legal Constraints

In popular culture, there is a perception that legal constraints do affect economic growth. Government regulations of business are often blamed for slower economic growth. Other legal constraints may keep the unemployed from earning an income. For example, trespassing laws prevent the unemployed from picking and selling nuts and fruits outside of their own private property.

There are also social constraints and influences. People are social animals and do not want to be odd. They do not want to stray far from social norms. This is one reason why people display more cooperative behavior than what traditional neoclassical economic models suggest. In my model, the bulk of the benefits going to the wealthy may just be a social norm. In standard economic theory, this can occur if most businesses earn an above normal profits.

However, because these constraints are not physical laws of nature, they can be violated. Criminals steal money and some people are willing to give up popularity in order to buck the trend and deviate from social norms. Nevertheless, deviations from these man-made laws and influences impose a cost on the deviant.

5.2 More on Evolution and Survival Instincts

If humans did not have survival instincts, they may have become extinct centuries ago. Although humans are capable of rational thought, humans developed apparent irrational traits such as fear, empathy and love which have survival value. See Robson and Samuelson (2010). These emotions may have greater survival value than rational thought. For example, when a man eating bear raids a campsite, the emotion of fear provides impetus for people to take action to avoid or confront the bear. The bear is most likely to eat the person who stands still while contemplating the best solution to avoid the bear. The people who flee, fight or play dead with little thought are the ones who survive.

In addition, having a perfect brain will not be optimal for survival purposes. Such a brain may require too much energy for the organism to survive. Thus, most people learn by doing. This is why investment in human capital is important. I will incorporate human capital into my model, and stress that utility maximization is a goal and not a description of actual human behavior.

Survivability may also explain why workers demand minimum wage and why unemployment existed even when there were no minimum wage laws. For poor people, a job has to satisfy survivability considerations. People will not take jobs if the employment does not result in increasing the person's probability to survive to an acceptable level.

This law of survivability may allow redistribution of income policies to have positive effects on economic growth. Because people must consume a minimum quantity of necessity goods to survive, they will save less than wealthy people who are in no danger of starvation. Thus, some redistribution of wealth from rich to poor will increase aggregate consumption and possibility national income. Moreover, a redistribution of wealth may allow poor people to invest in production increasing economic growth, provided that disincentive to work effects do not dominate the positive effects of redistribution.

One important note is that the minimum expenditures requirement can be thought of as having a marginal propensity to consume (MPC) of 100 percent. Satiation may be thought of as having a MPC of zero. Although this perspective is valid, I prefer the former notation because I do not want to attribute economic phenomena to tastes. Rather, I want to attribute these critical points in consumption as biological and physical limitations.

5.3 What Does the Data Say?

Scientific and economic theories must be able to explain the data. If they are inconsistent with the data, the theorist must explain why and what conditions the theory would be consistent with the data. If they do not, then no matter how elegant and beautiful the theory is, the theory is worthless.

Illustrated in Table 1 is inequality data taken from Thomas's Piketty's book "Capital in the Twenty-First Century (Table 7.3, p. 249).

Income Group	Europe	United States
Top 1%	10%	20%
Next 9%	25%	30%
The middle 40%	40%	30%
The bottom 50%	25%	20%
Total	100%	100%

Table 1: Inequality in total income in the United States and Europe as of 2010.

The data shows that income inequality is greater in the United States than in Europe. In Europe, the top 1 percent households, earn 10 percent of the total income. In the United States, the top 1 percent earn 20 percent of the total income. But what is more striking is that the inequality in wealth or capital is even greater than the inequality than income. According to Piketty, this spread in equality has been increasing over time. The inequality in capital is illustrated in table 2.

Wealth Group	Europe	United States
Top 1%	25%	35%
Next 9%	35%	35%
The middle 40%	40%	30%
The bottom 50%	25%	20%

Table 2: Inequality in Capital in the United States and Europe as of 2010.

According to Piketty, the source of growing income inequality is $r > g$. Because wealthy people derive most of their income from capital, such as stocks, bonds, and hedge funds, their income grows faster than those who rely mostly on wage income. But even if this view is valid, could another source of wage inequality be that of satiation and a minimum expenditures requirement? In this view, poor people spend all of their wages just to survive. On the other hand, once a wealthy person becomes saturated in consumption and human capital, he or she becomes free to accumulate capital with little bound.

According to the CBO, since 1979, higher income groups have seen their incomes grow faster than lower income groups. The income growth rates for the top 1 percent, 80-99, 20-80 and 0-20 percentiles were 275, 65, 40 and 18 percent respectively. See Harris and Sammartino (2011). From Figure 4 of the CBO report, the second quintile appears to have experienced about 25 percent growth, the middle quintile about 35 percent growth, and the fourth quintile just under 50 percent growth.

6 Building the Model with Survival Instincts

I argue that survival instincts or animal spirits can cause the economy to deviate from traditional macroeconomic models. Specifically, policies that redistribute wealth from rich to poor can increase economic output. Another deviation from RBC models is that agents do not necessarily smooth their consumption profiles. See Friedman (1957) on his permanent income hypothesis. But first, I argue why rationality is an unrealistic assumption in macroeconomics.

6.1 Evolution of Irrational Utility

Most economic models assume that people are rational. But we have seen that evolution may not favor genes of the most rational people. The following is an example why evolution may favor genes in people with irrational brains.

Suppose there are two variants of a money supply expectations gene $MSE1$ denoted as $MSE1a$ and $MSE1b$, in type a and type b people, respectively. These genes determine how a person reacts to an increase in money supply. Those with type a genes have money illusion. When the Federal Reserve prints money to increase the money supply, type *a* people believe that they are getting wealthier. On the other hand, when money supply contracts they think that they are getting poorer. Type *b* people are inflation paranoids and believe that when the Federal Reserve increases the money supply inflation will explode making them poorer. Likewise, when the money supply contracts, they believe that wealth will increase.

Suppose the economy goes into recession. The Federal Reserve decides to increase the money supply on the belief this will stimulate the economy. Type *a* people believe that they are getting wealthier so they go on a spending spree which does stimulate the economy. However, type *b* people save more on the belief that they are getting poorer, which has the effect of contracting the economy. If the two populations are about equal, then the errors cancel out and increasing the money supply will have no economic growth effects. Systematic error occurs if one population is much larger than the other. If type *a* people dominates, then the economy will grow when the money supply increases. But if type *b* people dominate, then increasing the money supply will cause the economy to contract.

Evolutionary theory states that mutations are random. Thus, we can postulate that there might be a money supply rational expectations gene $MSE1r$ where people inheriting this gene would correctly believe that money supply has no effect on wealth. Hence, if everyone were to have this gene, increasing the money supply would have no effect on economic growth.

Rational genes might not have a survival advantage because it's the environment that determines which traits are advantageous. For example, in an environment where type *a* genes are more prevalent than type *b* or type *r* genes, when money supply is increased during a recession, the economy really does get stimulated. Moreover, increasing the money supply may increase economic growth if it induces poor people to spend the money as if they were wealthier. In this case, type *a* people followed the optimum strategy and have the advantage to survive the recession. In the long run, type *a* people become even more dominant.

6.2 The Survivability Function

I claim that survivability and the distribution of income can influence macroeconomic variables. Because distribution of wealth matter, we cannot use a representative agent model. Rather, we need to look at different agents with different wealth levels. I start with the Kydland and Prescott Time to Build model described in Section 3 as our starting point.

Chatterjee and Ravikumar (1997) studied the effects of the minimum expenditure (ME) requirement in India. They discover that economic behavior in poor countries is quite different than wealthier countries. They postulate that because people do have minimum expenditure requirements, they must use much of their income and productive capacity just to buy basic needs that are necessary for survival. Therefore, poorer countries have less resources and money left over for other types of spending such as investment spending. This causes poorer countries to experience lower growth rates.

I claim that in the real world utility maximization cannot occur until the agent can be sure that she will survive the current period. I theorize that the agent with few resources will attempt to stay alive for as many periods as she can. Thus, even if credit markets are efficient and the agent can receive loans, she will consume all of her wealth to survive the next period to avoid death if necessary. Her first priority will be to eat food. Her next priority will be to find clothing and then shelter, which sometimes include cars. For the sake of simplicity, I will not distinguish between different types of consumption c_t. The household's goal is to maximize an expected well-being function ψ that depends on a survivability function s and discounted utility function v; subject to her resource constraint:

$$max \sum_{i=1}^{\infty} \beta^{T-1} \psi\big(s(c_t), v[s(c_t), c_t]\big) \tag{8}$$

such that

$$Y_t = A_t f(k_t, h_t, l_t) = c_t + k_{t+1} - (1-\delta_d)k_t \tag{9}$$

where E is an expectations operator, δ_d is the depreciation rate of capital, β_t the discount factor at time t, and h_t is human capital. For the sake of simplicity, we will ignore uncertainty.

When the ME requirement is binding, consumption is broken down into two parts. Let ε be the ME quantity of consumption, and c_o the quantity above the ME requirement, then:

$$c \geq \varepsilon, \;\; c = c_o + \varepsilon \tag{10}$$

Human capital theory was first developed by Schultz (1961) and Becker (1964). According to Schultz, human capital includes health, formal education and on the job training. Human capital evolves over time just like capital:

$$h = h_{t+1} + (1-\delta_h)h_t \tag{11}$$

where δ_h is the depreciation rate of human capital.

Implicit in Piketty's story, is that class mobility in the United States is small. Therefore, within class labor income is fixed and grows proportionally with economic growth. For the purpose of this paper, this assumption is appropriate since I am concerned more about the overall effects of distributing income from the wealthy to the poor than whether it is rather easy for a person to move from one income group to another. Nevertheless, allowing for class mobility is a subject for future research.

I have also added satiation limitations for consumption, human capital stock and momentary human capital to the model. Let c_t^s, h^s and h_t^s, be the satiation points for for consumption, human capital stock and momentary human capital. The following conditions must also hold:

$$c_t \leq c_t^s, \;\; h \leq h^s, \;\; h_t \leq h_t^s \tag{12}$$

If the individual is rational, she will solve her maximization problem in three steps. Her first step is to determine what consumption level is required to satisfy the minimum acceptable quantity of survivability α, which would be written in terms of a probability of survival. That is choose k_t, h_t and c_t such that:

$$s(c_t) = \beta^{t-1}\alpha \tag{13}$$

where $t = 1$ in period 1 so in the first period $s = \alpha$. Equation 13 states that the agent will choose to make no capital and human capital investments in period 1 until she consumes enough goods such that the probability of her survival in period 1 equals the minimum acceptable probability of survival α. If wealth is less than the consumption required to satisfy (13) then her solution will be to consume all of her wealth; therefore, consumption smoothing is not possible. At certain income levels, the agent will consume the minimum satisfactory amount one period, the remainder of her wealth in the following period, and then die in the last period.

One consequence of this result is that these low income economic players will act as if they were myopic. If the government gave them a tax rebate or gave them cash, they would spend the entire proceeds, thereby stimulating the economy.

Once equation 13 can be satisfied she'll check to see if the equation holds for period 2, and then for all time periods. If not she'll consume the minimum consumption requirement until the remainder of wealth is gone. If she consumes much less than the minimum requirement she dies of starvation or illness due to her poverty. Once equation 13 is satisfied for all periods she can maximize her utility subject to her resource constraint.

If the individual is wealthy, she will then reach a point of satiation in one or more of the choice variables. If she satiates in consumption first, then she will choose only between capital and human capital. If she satiates in momentary human capital first, she will expend h_t^s amount of human capital, keeping the relative spending between capital and consumption the same as if human capital was not satiated. If she satiates in human capital stock, human capital expenditures will equal its depreciation rate. Finally, if she satiates in all three variables, she will invest all of her remaining earnings into capital.

Notice that although ψ and v are different functions, they share many of the same properties. They are both concave and increase with rising consumption. Thus, for agents that have satisfied their survivability requirements, they behave very much the same way as utility maximizers. Therefore, the unsatisfactory fulfillment of the survivability requirement is the source of inefficiency in a survival instincts economy.

But if we are going to let economics be understood in the light of evolution and genetics, we must also identify other economic variables that determine survivability. In a more complex model, the advice of experts during time t, Ω_t, and the consumptions of others C_t may change our expected survivability. Moreover, emotions such as fear and excitement may affect our perception of expected survivability and thus change the parameters of the survivability function. Therefore, we could write the problem as:

$$max \;\; E\beta_t \psi\Big(s(c_t, \Omega_t, C_t),\; v[s(c_t, \Omega_t, C_t), c_t]\Big) \tag{14}$$

subject to the resource constraint. In a sense, these "animal spirits" variables act only to change the nature of the representative's preferences. Thus, while animal spirits may change the shape of demand curves, they do not in themselves cause inefficient outcomes. Here, survivability has both a necessity and preference component. In this model, only the necessity component can cause inefficient outcomes.

Therefore, the true reason behind inefficient outcomes is the existence of low income agents. In order for animal spirits to cause inefficient outcomes is for them to cause true mistakes such as a violation of the transitivity condition, transversality condition or on how they assess economic variables such as risk. I argue that the fact that most people feel more grief over losing a child rather than never having a child is a matter of preference and not irrational as standard economic theory would suggest. Excessive pain from losing a child has survival value because it induces us to protect our children. The observation that people feel more pain from losing money than the elation they feel when they gain the same amount of money is a logical outcome of evolution and natural selection. See Thaler (1994).

In this research, I do not assume that agents are hyper-rational. Because of biological limitations, they will spend all of their earnings on food before they allocate earnings on capital and human capital spending. However, there is no proof to the form of the average person's utility function. There is not even proof that most people know what they want. Most likely, they will purchase a consumption good and when they actually consume the good decide whether it made them happier or not. If the good makes them happy, they may buy some more goods.

In many ways, this sensory feedback process, also known as perceptual control theory, follows the work of Brainard and Sobera (2012), where songbirds use an auditory feedback system to sing in harmony with other songbirds. In their model, an auditory feedback system is compared with a sensory target, and any perceived deviation or error from the average pitch of the sounds from the other songbirds are used to drive modifications of the the singer's vocal motor system. However, I do not attempt to mathematically model the control system. In this research, I will assume that greater earnings lead to greater consumption until satiation is reached. In the figure below, the sensory feedback system is used to determine whether one should continue eating or stop. I will check to see how the results change as certain parameters such as the MPC vary. A person eats, then receives sensory feedback of whether the food tasted good or whether he or she is still hungry. The person then compares this feeling with a target feeling and then uses her motor system to take action to better match with the sensory target.

One difference this model has with the traditional neoclassical models is that consumption smoothing may not occur even if the individual has income well above the ME requirement. In this model, the individual may one day wish to take an expensive vacation. Thus, the individual may save her income for a number of years until she can afford the expensive vacation or when economic conditions are favorable for such a vacation.

Once we describe how households choose their consumption, human capital and capital goods allocation, conservation of mass conditions are imposed, namely:

$$Y_d + J = Y_s \tag{15}$$

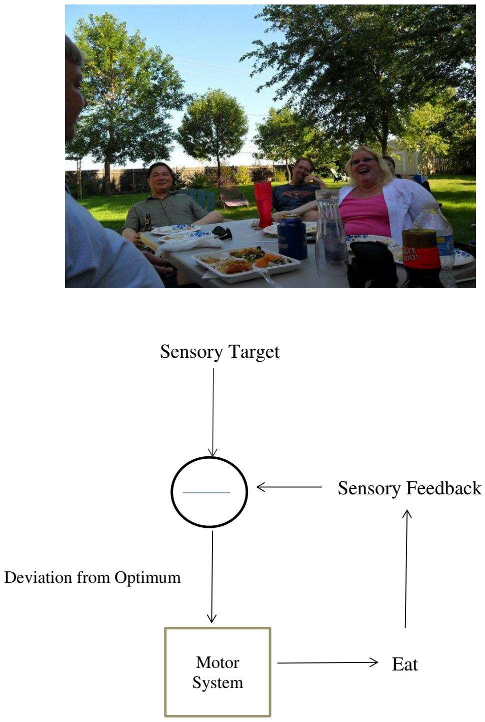

Figure 1: Illustration of how sensory feedback is used to determine whether to consume more or to stop. The diners depicted above must continuously decide to whether to eat more food or stop.

where j is inventory produced in the current period. In addition, the inventory stock depreciates at a rate δ_j and must always be positive or

$$J = \sum_{i=0}^{T} (1-\delta_j)^i J_{T-i} \geq 0 \tag{16}$$

where J is the total stock of inventory. As mentioned above, government statistics includes J as part of investment. Moreover, the markets clear if $J = 0$. In other words, aggregate demand equals aggregate supply.

6.3 Aggregation

The government does keep aggregate statistics for GDP and its components. But if distribution of income is important in determining aggregate variables such as consumer demand and investment, then knowing the income distribution is important, too. The government and macroeconomist forecasters would want to know how many people fall within various income groups. If the survival model is valid, the researcher may want to split the consumption data between those people whose income levels falls below the minimum probability of survivability requirement, and those who have adequate income. In my model, their are six income groups: (1) The top .1 percent, (2) the next .9 percent, (3) the 90-99 percent, (4) the 50-90 percent, (5) the 10-50 percent and (6) the 0-10 percent. These groups correspond to Piketty's categorization except I break down Piketty's bottom 50 percent group into group 5 and 6 to add greater insight. Therefore, aggregate consumer demand is

$$C = C_1 + C_2 + ...C_6 = (\omega_1 + \omega_2 + ...\omega_6)C \tag{17}$$

where ω_i denotes the share of group i in the economy, $\omega_1 + \omega_2 + ...\omega_6 = 1$, C_i the total consumption of group i.

As mentioned earlier, I use CBO and Piketty's data estimating the shares of each income group. Another possible source of data would be bankruptcy filing data. Bankruptcy filing data could give researchers insight on how the consumption behavior of very financially stressed people. However, because of attorney-client privilege, such data would be difficult to obtain.

7 Economic Simulations

To see the effects of redistribution effects on the economy, I ran simulations of the model. Because this economy contains several discontinuities, developing a computer program is quite complex. Economic equations change when critical values are reached, making it necessary to use many nested if statements in the computer program. In the early years of an economy, capital accumulation causes the economy to grow at a rapid pace. Economic growth slows when capital accumulation converges to a positive value. However, I want to explore how the model responds when $r > g$ and when $r = g$. To make the model consistent with the experimental design, I have to construct the following story:

7.1 Experimental Setup

In the first period, one million people form a new medium sized city in a large country. This assumption allows individual incomes and wealth to grow without affecting the growth rate of the large economy. By fate (because they were born in households with little human capital) or because of decisions made during adolescence, households are locked into the six income groups mentioned above. Economic growth driven by technology shocks A_t, are assumed exogenous and are set by the experimenter.

At the end of each period, economic growth or decline is divided as suggested by Harris and Sammartino (2011). Because the real value of federal minimum wage has generally fallen since 1968, I assume that the bottom 10 percent do not directly share in the gains of economic growth. See Elwell (2014). This implies since 1979, each of the income groups, top .1 percent, next .99 percent, 50-90 percent, 10-50 percent and 0-10 percent shares were 2.5, 4.1, 17.2, 50.8, 25.4 and 0, respectively.

I normalize the total income of the city to be ten million in the first period. This corresponds to an initial base wage of each income group in dollars to be

750, 138.90, 33.33, 7.50, 4.00 and 2.00. In the case where no ME requirements and satiation limitations are set, I presume that the household's solution to their problems are in the form of:

$$c_t = m_c Y, \tag{18}$$

$$k_{t+1} - (1-\delta_k)k_t = m_i y, \tag{19}$$

$$H_{t+1} - (1-\delta_h)h_t = m_h y \tag{20}$$

where m_c is the marginal propensity to consume, m_i is the marginal propensity to invest, and m_h is the propensity to invest in human capital. These marginal propensities must sum to one.

In the experiment I vary the marginal propensity to consume. However, I am most interested in the setting of m_c .95, approximately the average marginal propensity to consume since 2008. I then set the marginal propensity to invest and to invest in human capital to be .025. I also vary the depreciation rates. I suspect that on average human capital depreciates faster than capital. Remember, capital is also composed of assets with little depreciation, such as gold bars and cash. However, I argue that inflation is a form of depreciation.

I also run simulations where the ME requirement is set at \$4.00. This means that every person who has an income less than the ME amount, uses all of her income for consumption. I also set a satiation point for consumption at \$160. Once a household consumes more than \$160 in a period, she pours the remaining income above the satiation amount into human capital and capital. This changes the marginal propensities to consume and to invest in human capital. The new marginal propensities are denoted as m_{ics} and m_{hcs}. Once a choice variable is satiated, the marginal propensities for the remaining quantities sum to one and the marginal propensities retain the same ratio as if no quantity was satiated. If the household becomes satiated in human capital, then the marginal propensities to consume for consumption and capital become m_{chs} and m_{ihs}.

Human capital has both a short run and long run satiation point. In any given period, the household is willing to only spend \$20 dollars in human capital. But in the long run, the stock of human capital has an upper bound of \$80. This means once the 80 dollar limit is reached, the household only expenditures on human capital is to replace the human capital that depreciates. The human capital limitations appear to be reasonable if we assume that human capital consists of mostly education and job training. However, it seems reasonable to assume no satiation point if we include health as part of human capital. For reference purposes, I call the model consisting the ME requirement and all of the satiation limitations as the "model with discontinuities."

Allowing for the ME requirement changes the solution form in equations (18) - (20). The form becomes:

$$c_t + \varepsilon = m_c(y - \varepsilon), \tag{21}$$

$$k_{t+1} - (1 - \delta_k)k_t = m_i(y - \varepsilon), \tag{22}$$

$$H_{t+1} - (1 - \delta_h)h_t = m_h(y - \varepsilon) \tag{23}$$

Notice, I do not assume that the economy has to be in a supply equals demand equilibrium. A household may accumulate unwanted inventory, which is regarded as an accumulation of capital.

7.2 Results of the No Redistribution Economy

I first ran simulations for 30 periods assuming that government conducts no wealth or income redistribution policy. I then compared the results to an economy where government redistributes wealth from the wealthy to the poor, in the form of human capital. In general, Piketty's claim that $r > g$ is the reason for growing inequality in the United States is only accepted in the short run. In the long run, $r > g$ is not a sufficient condition for long run divergent income distributions. Only under special circumstances does this inequality lead to divergent growth, once the initial stages of capital growth is completed. Most likely, the divergence in Europe seen after World War II is due to the war destroying much of Europe's capital stock: Europe entered a new initial phase of capital growth. Thus, wealth among the different groups are converging to different steady state levels, which will no longer diverge once the initial stages of capital growth is completed. However, in the initial stages of economic development, the model did find the top .1 percent group gaining shares in wealth as the bottom ten percent lost shares as illustrated in figures 2-4. I found no circumstance when $r = g$ did income shares diverge in the long run.

In figure 2, the capital profiles for each group are concave despite that the return on capital is 20 percent, while the economy only grows at one percent. Figure 3 compares the initial and final wealth or capital distributions. However, this result is an artifact that higher income groups receive the most benefits of economic growth.

From figure 3, one can see that wealth among the top one percent increased from a 20 percent share of aggregate income to to a 23.3 percent share. The bottom 10 percent saw their share drop from two percent to 1.3 percent.

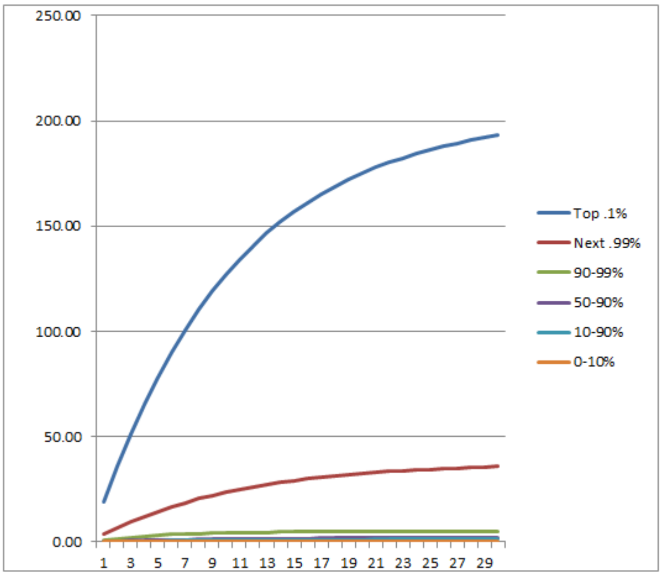

Figure 2: The capital accumulation profiles for each income group is concave even in a low economic growth but booming assets economy. Here, $r = .2$ and $g = .01$.

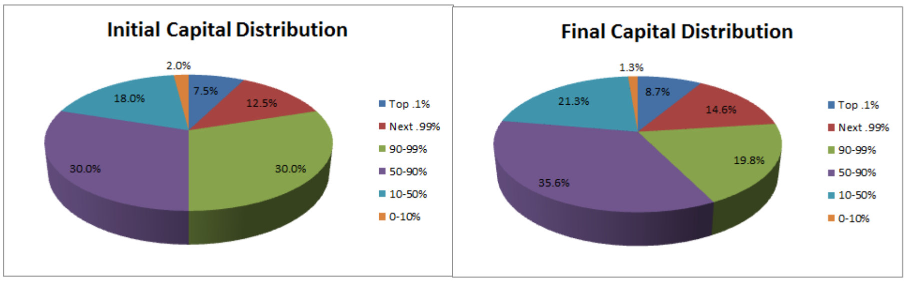

Figure 3: Initial and final capital (wealth) distributions among the income groups.

The special circumstances that wealth distribution appears to be divergent is when depreciation of capital stock is low, say five percent or lower, $r > g$, and the most wealthy households reaches a stage of consumption satiation. Moreover, a tax cut to the top income earners will make it appear that wealth is diverging, but this appearance is only temporary unless the wealthy receives an endless series of tax cuts, which are paid by the remaining income groups.

In figure 4, on the left side is an illustration of the capital stock profile in the model with discontinuities. The convexity of the profile implies that wealth shares are diverging within the appropriate time period. On the right side is an illustration of a tax cut that occurs in period 11. In the initial period, taxes are set at 80 percent of income over \$160, then the tax bracket is raised to \$320. The capital stock profile becomes locally convex, but after a period of time, returns to a concave shape.

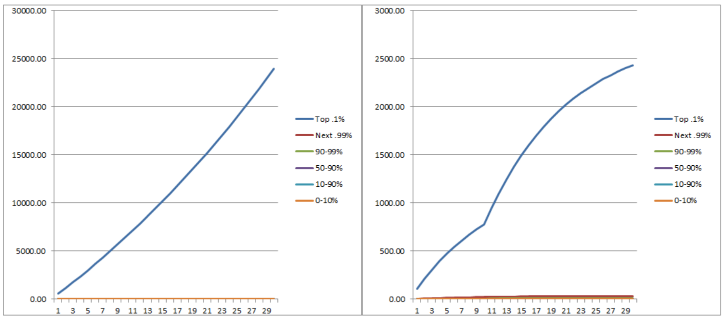

Figure 4: Illustration of the effects of satiation and minimum expenditure requirements (left side). On the right side is an illustration of the effect of a tax cut.

In both cases, the top .1 percent's share of wealth grew dramatically. With the tax cut, the top .1 percent's share grew from 44.9 percent to 64.2 percent. In the model with discontinuities, the top .1 percent share grew from 80.7 percent to to 92.5 percent. Obviously, the results of the model with discontinuities errs on the side of predicting too much inequality. However, a better match of the data might be obtained by relaxing the conditions of the discontinuities.

The growing divergence inequality occurs because the top .1 percent reaches the satiation point in consumption and in both short-run human capital expenditures and long-run human capital stock. Thus, these wealthy people can pour all of their remaining income into capital. If they invest in capital or wealth that experience little depreciation, their wealth holdings can explode. Meanwhile, the bottom ten percent must spend all of their wealth on consumption and invests no earnings in capital accumulation nor human capital accumulation. This means that the poor are trapped to remain in their income group.

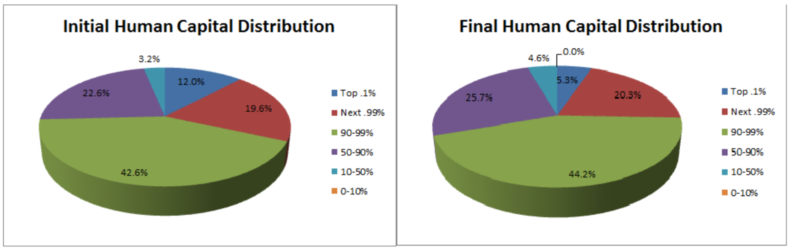

Figure 5: Initial and final human capital shares in the model with discontinuities.

One may be surprised to see that human capital shares have fallen for the top .1 percent from 12.0 percent to 5.3 percent. However, this occurs only because of the short run and long run satiation assumption. In the next subsection, we will see what happens when the top .1 percent are taxed in order to pay for part of the bottom 90 percent's human capital expenditures.

7.3 Results with Redistribution of Income

Although Piketty's law in the long run is rejected, he is correct in stating that inequality may be increasing because of economic policy. A series of tax cuts benefiting mostly upper income groups combined with minimum expenditure and satiation conditions can cause the income distribution to temporarily diverge. Although divergence may be temporary when compared to the age of the economy, temporary may be a century or so, a long time when compared to the average life expectancy of a human.

We see above that under certain conditions, wealth distribution among the income groups will diverge until the top few income earners will own almost all of the nation's capital stock. Piketty has suggested an 80 percent tax above incomes of somewhere between $500,000 or $1,000,000 in the United States. This corresponds to about 10-20 times the average salary. In my model, I taxed incomes above $160 or $320. This taxation policy is somewhat more generous than Piketty's suggestion as the tax bracket begins at 16 or 32 times the average earnings. Nevertheless, the economic outcome is quite dramatic if the tax revenue are used to compensate the bottom 90 percent of households. The effects are dramatic even though only $344,000 or about 3.44 percent of aggregate income in tax revenue are collected and distributed in equal amounts to the bottom 90 percent.

Taxing the top .1 percent changes their convex capital accumulation profile into a concave profile. Moreover, redistributing wealth allows lower income groups to accumulate human capital. Aggregate human capital rises by 8.1 percent. See figure 6. Although not considered in this model, greater aggregate human capital may increase the probability of greater innovation in the economy, causing the technical growth parameter A to grow at a faster rate. However, the bottom 10 percent still do not invest in capital or human capital because their incomes are still below the ME requirement. Aggregate consumption rises by 5.1 percent. This means if New-Keynesian models are correct, then a balanced budget redistribution of income can boost GDP and can have counter-cyclical affects during recessions.

Alternatively, tax revenues can be used to fund human capital expenditures directly. This could come in the form of vouchers to job training programs, scholarships or building public schools. If health is considered as part of human capital, this could also include programs such as medicaid or subsidies to pay for health insurance. The right side of figure 6 shows that such a policy allows the poor

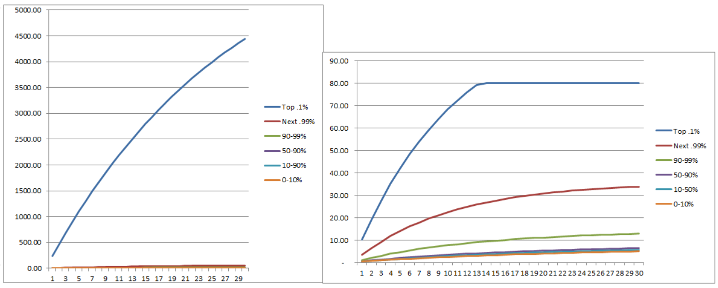

Figure 6: The left side illustration shows that a redistribution of income policy transforms a convex capital stock profile into a concave profile. The right side figure shows that the redistribution in income that subsidizes human capital expenditures lifts human capital expenditures in the lower income groups.

to obtain human capital when previously all income was used for consumption. This policy allows for greater human capital accumulation than the income subsidy policy, but the beneficiaries of the human capital subsidy will have less income for consumption than the beneficiaries of the income subsidy. Nevertheless, by helping lower income groups, the policy makers using either policy will increase both aggregate consumption and human capital expenditures.

But the policy comes with a price. The tax on the wealthy causes capital spending to plummet by almost 75 percent. If much of the capital that is no longer created is productive, then the economy could contract to a lower level of GDP. However, Piketty would argue that much of the wealthy's capital stock is nonproductive, which may include gold bars, cash, antique cars, vacant land, and speculative derivatives and exotic investments. Such a tax may also stabilize the economy as less earnings are poured into speculative exotic investments that fuel irrational bubbles.

Figure 7 summarizes the policy outcomes for the two different policies at two different sets of depreciation rates. The lower set where $\delta_k = .05$ and $\delta_h = .1$ is a low depreciation rate economy. Below is an illustration of the initial and final distributions of human capital. In these cases, the rate of return on capital r is set at Piketty's observed value of approximately .07 and the economic growth rate is set at .02. In that scenario, $r > g$, and existence of discontinuities, wealth accumulation by the top .1 percent is convex. Thus, such a policy does prevent runaway capital accumulation on the most wealthy people. The other set of depreciation rates, $\delta_k = .1$ and $\delta_h = .2$ represent a more realistic pair of rates. Although the capital stock profile among the most wealthy is concave, redistribution of income also results in higher human capital expenditures and aggregate consumption.

Final Distributions

	No Redistributions	Human Capital Subsidies	Percent Gain	Income Subsidies	Percent Gain
δ_h=.2, δ_k=.1					
Human Capital	816,056	3,235,232	296.4%	847,090	3.8%
Capital	12,812,757	3,933,585	-69.3%	3,800,776	-70.3%
Consumption	9,583,290	9,761,455	1.9%	10,068,416	5.1%
δ_h=.1, δ_k=.05					
Human Capital	1,503,889	6,798,927	352.1%	1,626,186	8.1%
Capital	25,894,901	6,918,979	-73.3%	6,556,078	-74.7%
Consumption	9,680,876	10,064,840	4.0%	10,273,194	6.1%

Figure 7: Summary of the effects income and human capital subsidy policies. Both policies raised aggregate consumption and human capital. However, capital accumulation was significantly lower than an economy with no redistribution.

The question for citizens will be whether redistribution policies are worth the slower rise in capital accumulation, and ultimately a lower aggregate capital stock. Whether such policies increases or decrease economic growth are hypothesis that have to be tested before we know the answer to that question.

8 The Hydrogen Bomb Economy of 2008

The model with discontinuities is best used to study long-term trends in the economy and not depressions and recessions. In the above experiment I was concerned more about overall aggregate or income group quantities, and not movement between the economic classes. Nevertheless, in the long-run, many workers follow a career path. Thus, most people work in the same type of employment for most of their lives. Although people can move up and down in along the economic ladder, much movement between the classes are often decided when a person is young. Thus, the model is applicable when studying long-term trends. However, when studying business cycles, we must study why economic fluctuations throw people off of career paths.

Real Business Cycle economists tried to explain technology shocks as the source of business cycles. However, for many economists, the concept of technical regress as a the source of recessions is not convincing. Thus, economists look at variations in capital stock accumulation (investment), consumption, government and variations in labor as explanations of the business cycle. The question becomes, what are the forces that act upon these economic variables? In previous sections, I have already mentioned a few sources. Wars, bad weather, pests, oil shocks and trade embargoes causes the economic balloon to shrink. In a addition, money illusion, and sticky prices and wages can cause the economy to function inefficiently.

But in this section I want to ask, what causes an economy to collapse as it did in the 1929 and 2008? To explain these collapses, think of the economy as a machine. In order for a modern day economy to work, money and credit are needed for smooth transactions to occur. This is where monetary policy becomes important. Theoretically, printing money other than helping the paper industry, does nothing to influence long-term economic variables. But in the modern day economy, money and available credit are needed for business activity to occur. Thus, gross debt is a good indicator of economic activity (net debt is zero). Money and credit is like grease that lets an engine run smoothly. Run out of grease, and the engine stops working.

I now postulate a production function of:

$$f(K,L,D) = Y \tag{24}$$

where D is gross debt in the economy. Gross debt is supplied by the financial sector of the economy. Gross debt is supplied by banks and other financial institutions provided that accumulated foreclosed property (AFI) is kept to a minimum. Foreclosed property is collateral that financial institutions are forced to collect when the debtor cannot repay her debts.

Concepts in nuclear physics can now be used to explain how the chain reaction of bank failures occurred and how it spread to the macro economy. In a typical hydrogen bomb, there are two chambers encased in a cylindrical warhead. In one chamber lies the boosted fission primary that is designed to detonate the fusion reaction with a fission reaction. The second chamber contains the fusion material. The bank failures were like a fission chain reaction, which then detonated the fusion reaction. The fusion reaction, an aggregation of debt defaults, caused the economy to collapse.

The economic hydrogen bomb also has two sectors. The first sector is called the financial/banking sector, and the second is the rest of the economy. In the economic hydrogen bomb, the explosion in the financial sector causes a bigger explosion in the real economy. For the economic hydrogen bomb, securities or high risk toxic assets such as highly leveraged bundled sub-prime mortgages that banks purchase as investments serve as uranium or plutonium in atomic bombs.

Once the fissionable material is mined and processed, they must be accumulated in sufficient amounts so that a chain reaction is possible. For the banking system to collapse, the banks must hold a critical amount of toxic assets so that a collapse of prices in these assets will make at least one bank fail. Then it must be massive enough so that the one bank failure will cause more bank failures, until the banking system collapses. Accumulation of toxic assets to a critical amount usually occurs during a speculative bubble.

For the bombs to be detonated there needs to be an initiator, a source that will cause the first neutron to be released that will split the first atom. Most bank runs require a first bank to fail. When this first bank fails (Lehman Brothers in 2008), rumors about other banks causes runs on those banks and eventually the bank run will spread to most other banks.

Banks also borrow and lend its assets to other banks. It's debts to depositors and other investors are used as loans to entrepreneurs who invest the assets in projects. When a bank fails, it defaults on its payments to other banks, causing other banks to lose liquidity needed to pay back their loans. Let $\Delta^{j}W$ be net withdrawals in dollars (withdrawals less deposits) that initiate a bank run, ${}^{ji}d$ denote defaulted assets on a loan from bank i to j, let ${}^{j}BD$ represent bank j's net debts (debts less assets or the negative of the shareholders equity), ${}^{i}A$ the sum of the banks remaining net debts purchased by other institutions, and μ a parameter greater than one. A bank run reaction can be represented as

$$ {}^{j}BD + {}^{ji}d + \Delta^{j}W \longrightarrow {}^{i}A + \sum {}^{ji}d + \mu\Delta^{j}W \tag{25} $$

where the value of the left side of the reaction equals the value of the right side of the reaction. Bank i's default on its debts to bank j or/and initial mass withdrawals from depositors causes a run on bank j. This causes bank j to fail. The bank liquidates because the initial withdrawals are magnified by a factor of μ defaulting on its debts to other banks represented by $\sum^{jk} d$, leaving the sum of its remaining assets to be sold, with the proceeds used to pay its creditors. Unfortunately, because bank j defaults on many of its payments, its creditors also experience bank runs.

Once the atomic bomb explodes, we still need to detonate the fusion bomb. This means there must be some linkage of the financial and banking sectors of the economy to the real economy. There are several linkages. The most common cited linkage is that banks have to become cautious in order not to fail. Thus, they will curtail their lending activities, and many big projects that were being planned will be delayed or abandoned. If lending activities plummets enough, then the economy can also crash.

One question asked, is why cannot banks bail themselves out by giving the weak bank loans? Perhaps, in ordinary times they might. But when banks give loans to other banks they like everyone else want to get paid back. During financial panics, there are many banks going under, and the banks do not know which bank holds large amounts of toxic assets and thus cannot pay back the loan. This causes interest rates on interbank loans to soar. One indicator of how easy it is for banks to borrow from other banks is called the TED spread index, which is the difference in the interest rates between a three month US treasury bill and three month futures Eurodollar contract also called the London Interbank Offer Rate, LIBOR. During financial crisis, LIBOR soars causing the TED spread to soar. During the Panic of 2008, the TED spread was twenty times above normal, causing interbank lending to halt.

Investors can also lose their assets if the bank they save at is not covered by FDIC insurance. After repeal of the Glass-Steagall Act, banks could invest in securities. This investment is not covered by FDIC insurance. Thus, investors lost their savings during the financial collapse of 2008 and cut their consumer spending.

Once the economic hydrogen bomb explodes, people take extra precautions to make sure they can survive to the next day or month. This means that even if they still have a job and are earning the same income as before, they will reduce their spending because they perceive that the probability that they will lose their job has gone up. This would lead the economy in a long-term recession.

Moreover, rising debt levels of households also causes consumers to take extra precautions. If consumers go bankrupt and lose their homes, then their probability of death rises. This effect will reduce consumption spending until households see their balance sheets improve. This causes recessions due to economic hydrogen bombs to last longer than ordinary recessions because the economy does not turn around until balance sheets turn around. This also applies to business. This is what Richard Koo calls a balanced sheet recession, Koo (2009).

The worst recessions are characterized by an accumulation of foreclosed property (F). When property is foreclosed, an economic transaction or trade is being repealed. The property becomes extra inventory or AFI. When too much inventory accumulates, production of the property (i.e. real estate) drops. Although net debt is always zero, gross debt is an indication of economic and trade activity. Not only less people are taking on debt to buy property, but debt from foreclosed property has to be written off or discharged in bankruptcy court. Thus, economic waste E is being created. Let the superscripts represent a number of units of property, the economic fusion reaction is:

$$^{1}F \, + \, ^{1}F \longrightarrow \, ^{2}AFI \, + \, E \tag{26}$$

9 Conclusions and Possible Extensions to the Research

In this paper, I used tools from gas laws, evolution theory to nuclear physics to study the macro economy. Like in science, in order of macroeconomics to make better predictions, the field must go beyond the Ideal Gas Law economy. Sometimes its better to use messy ad hoc techniques to study complex behavior than not studying the behavior at all. For example, solving complex systems such as fluid flow through a pipe through the prism of individual molecular behavior is not practical. Scientist use macro laws to solve these problems even if there are no microfoundations.

As an example, I developed a model with discontinuities. These discontinuities make it difficult to prove existence of an equilibrium. However, minimum expenditure requirements and satiation limitations are probably a good way at looking at individual behavior. Using data from Piketty and the CBO, I show that redistribution of income from high income groups to low income groups may increase economic activity. Such redistribution provides opportunity to obtain human capital, which can lead to economic mobility. However, the price of redistribution is a fall in the capital stock of the economy. Whether the net result is higher GDP depends on the relative productivity between human capital and capital stock, and whether increases in aggregate consumption can increase economic growth because of excess aggregate supply in the economy.

Many unreported simulations were conducted for this paper. Many conditions were studies, such as boom economies, stock market crashes, recessions and great depressions. Consequences of different policies were also run. A more careful analysis of these unreported simulations is also left for future research. In addition, the model I created allows for households to spend their capital stock when their incomes fall below the minimum expenditures amount. How debt can effect the economy is also a subject for future research. I also proposed a model of perceptual control theory as a possible direction for theories of consumption. Whether such a model will have different consequences than the rational expectations assumption could be a topic for further research. Externalities, such as climate change, and the economic growth and redistribution impacts of regulating these problems will also be an important research topic for economists in the future. In climate change models, population growth becomes an especially important variable

In many ways, physics and chemistry is simpler than economics. Atoms do not have a conscious mind. Economists have to model economic actors that have free will. Although actors have biological limits, they are free to choose what they want to eat and what occupation they want to work in. This requires extensive mathematical calculations and relative simple models that have no chance of approximating reality. This means that the tools that economists use should be eclectic and not limited to DSGE models.

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