| | |
|---|---|
| **From:** | John H. Detweiler |
| **To:** | SENR Exhibits |
| **Cc:** | Rep Dan Rayfield; Mike Nearman; Sara Gelser; Rep BoshartDavis |
| **Subject:** | CONCERNS WITH CARBON CAP-AND-TRADE BILL (LC 19) |
| **Date:** | Tuesday, January 14, 2020 4:56:37 PM |
| **Attachments:** | On_CCBS.pdf<br>earth-support.pdf |


Sir:

Be careful what you do with LC 19, the new cap and trade effort. You are liable to condemn rural Oregonians -- and maybe others -- who use a lot of fossil fuel in making a living to a life of poverty for what at best, will be an insignificant reduction in greenhouse gases. If you do destroy rural Oregonians economically, you will exacerbate homelessness and other social problems.

Attached are two papers. The first cuts through the climate change drivel in the popular press and defines the problem. It requires nothing more than high school algebra to understand. The second paper deals with the problem in greater complexity than the first but if one is not into math/stat, everything after the first page (plus) can be ignored.

My name is John H. Detweiler. I am retired and live in Corvallis. If this bill becomes law, it will affect me directly by raising prices and indirectly by more homeless people coming to Corvallis.

Again, be careful what you do. Whatever Oregon does with respect to greenhouse gases will be nothing but noise in the earth's thermodynamic system. If there is any doubt in your mind, I am against LC19 becoming law.

John H. Detweiler; web page => http://www.peak.org/~detweij

April 8, 2015

# CUTTING THROUGH CLIMATE CHANGE BULLSH!T

By
John H. Detweiler
detweij@peak.org

There is a great deal of BS in the popular press these days about climate change. It comes from both the followers of Saint Al Gore, and from the climate change deniers. Virtually none of it is worth reading. In my opinion, we are inundated with this BS because the voting public is woefully ignorant of science. Moreover, our leaders are all too often people who did not study calculus and physics in college, which compounds the problem. In other words, there are simply too many people who have no idea how the physical world really works having a say about what should be done about climate change.

The purpose of this paper is to present a simple explanation of climate change without unnecessary detail, discuss carbon dioxide as an insulator, and present what I think is the real problem. At the end is an epilogue.

## A Simple Explanation of Climate Change

Our cars and the earth are thermodynamic systems. We put energy into our cars in the form of gasoline – chemical energy. We then transform that chemical energy into kinetic energy with the engine. Some of that kinetic energy is stored in the flywheel, and some is transformed into electrical energy and stored in the battery. The remainder of that kinetic energy is transformed into work – driving around – or exhausted from the system as waste heat.

The law that cars, the earth, and thermodynamic systems in general are subject to is the "first law of thermodynamics"[1].

[1] A statement of the first law of thermodynamics can be found in physics and engineering books. A reference I use is David Halliday and Robert Resnick, Physics for Students of Science and Engineering, John Wiley & Sons, 1960, my college physics textbook.

This law can be expressed as an equation; energy into the system equals energy stored in the system plus work plus energy out of the system:

$$E_{in} = E_{stored} + Work + E_{out}.$$

Rearranging terms:

$$E_{in} – E_{out} = E_{stored} + Work.$$

In the case of the earth, ($E_{in} – E_{out}$) is the difference in the solar radiation coming to the earth and the energy radiated by the earth. If it is positive, energy is being stored ($E_{stored}$) in the air, water, and ice (by melting) and expended in the creation of weather (work) – which in this context is not only the weather we see from our porches, but the movement of ocean water masses. If ($E_{in} – E_{out}$) is zero or negative, energy is being extracted from ($E_{stored}$) and used to create weather and/or radiated out into space.

Figure one[2], shown below, shows the net radiation ($E_{in} – E_{out}$) for the earth. In this graph, it has been positive since at least 1990. According to the graph, all of the net radiation until 2005 has gone into storage. Since 2005, some of the net radiation has not been found. My guess is that, if the measurements are valid, the energy has gone into areas that we do not monitor well or into creating weather.

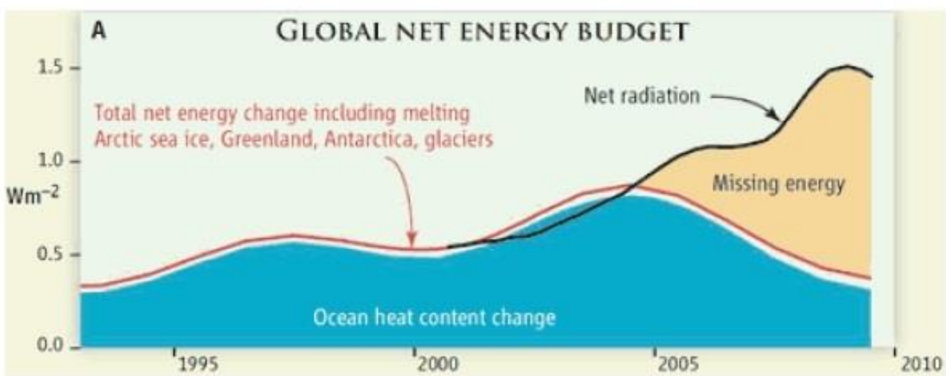


Figure One

[2] Figure one, the global net energy budget, comes from K.E. Trenberth, J.T. Fasullo, Tracking Earth's Energy, Science 16 April 2010, DOI: 10.1126/science.1187272.

Carbon Dioxide

Carbon dioxide acts as an insulator, not unlike the insulation in our attics, reducing the radiation of energy back to space ($E_{out}$ ). Figure two[3], shown below, is a graph of $CO_2$ concentration over time. As shown in the graph, the insulation in our attics has been increasing over time.

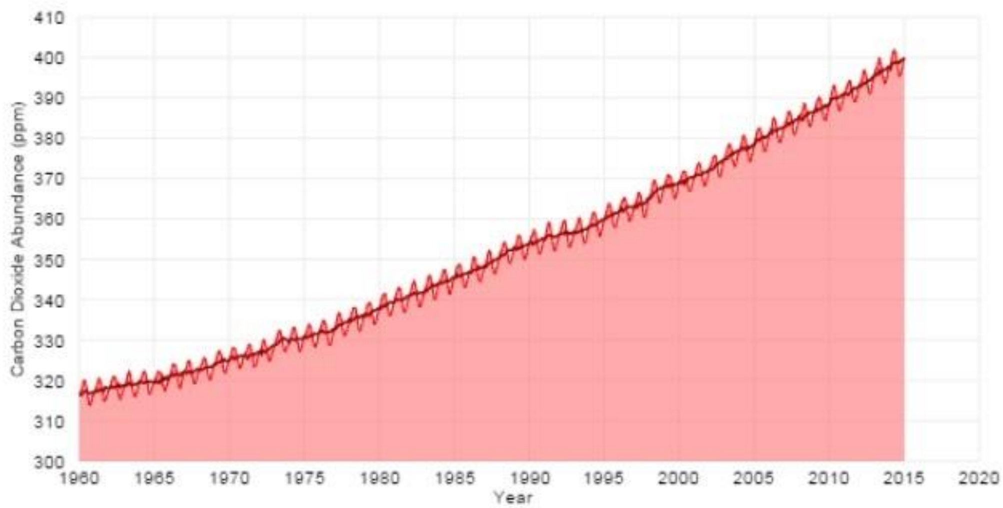


Figure two

The disciples of Saint Al want to shut down, or mostly shut down, the world's use of fossil fuels to reduce the amount of insulation in our attic. In my opinion, this is not going to happen because developing countries want cheap and reliable energy to achieve a standard of living equal to that of the developed world. Their expanding use of fossil fuels for that purpose renders hopeless the current efforts in Oregon to reduce global $CO_2$ emissions. Even more hopeless is the efforts of the Corvallis City Council to reduce global $CO_2$ through setting council goals.

As more and more people acquire cheap reliable energy – which, at this point, comes from fossil fuels – I expect that the amount of $CO_2$ in the atmosphere will increase.

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[3] This graph comes from the NOAA website, Climate.gov. Quoting from the website, "During the Industrial Revolution, humans began burning coal, natural gas, and oil to power machines for manufacturing and transportation. Since then, we have burned more fossil fuels each decade, releasing vast amounts of carbon dioxide that were previously stored in the ground into the atmosphere. Before the Industrial Revolution, the atmospheric concentration of carbon dioxide was about 280 ppm. When continuous observations began at Mauna Loa in 1958, carbon dioxide concentration was roughly 315 ppm. On May 9, 2013, the daily average concentration of carbon dioxide measured at Mauna Loa surpassed 400 parts per million for the first time on record.

Figure three[4], shown below, shows what would happen if the use of fossil fuels were terminated at various levels of $CO_2$. Notice that the $CO_2$ drops relatively quickly and stays relatively high for at least one thousand years.

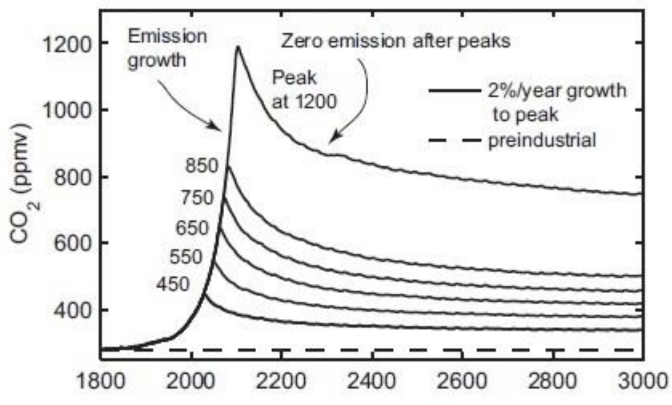


Figure three

In other words, cutting $CO_2$ emissions is not going to do much good. Moreover, there is not much we can do except to try geoengineering schemes to reduce solar radiation coming to the earth ($E_{in}$ ) which may have unintended consequences. Like it or not, we will have to adapt to the anticipated changes.

[4] This graph comes from an article by S. Solomon, GK PLattner, and et.al. Irreversible climate change due to carbon dioxide emissions, dated December 16, 2008, published www.pnas.org_cgi_doi_10.1073_pnas.0812721106.

The Real Problem

The real problem is the increasing world population. Figure four[5], shown below, shows how the population is increasing.

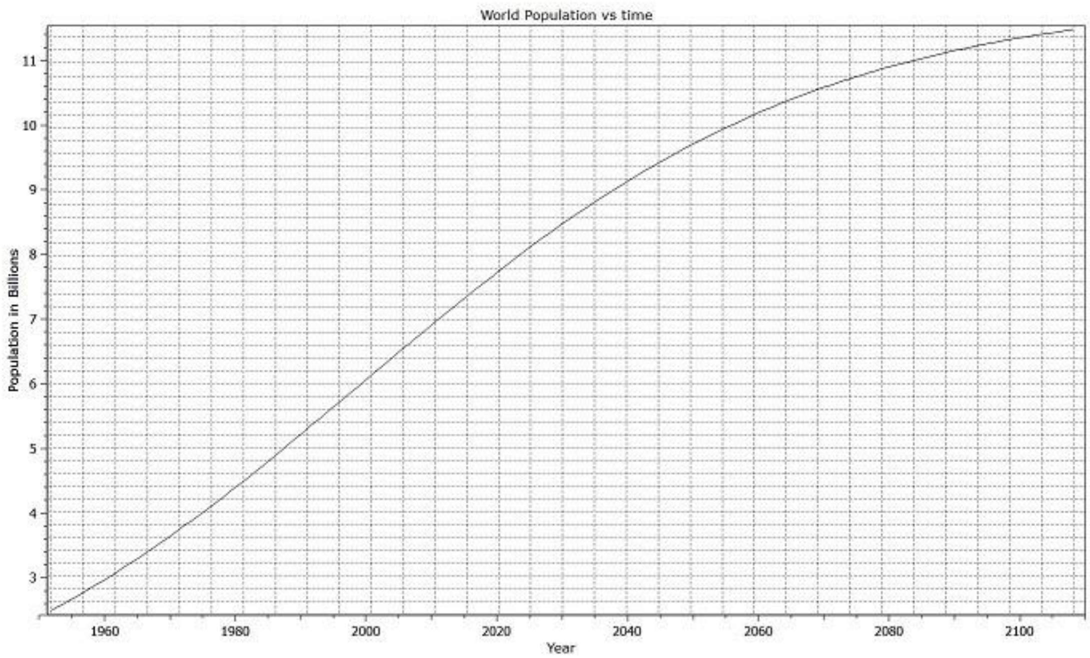


Figure Four

This curve is the classic S shaped curve asymptotically approaching a maximum of twelve billion people. Early in the next century, the population will be at 95% of the asymptote. The shape of the curve is driven by the data, which does appear to reflect changing fertility rates. If the reader thinks the fertility rates are not correct, he/she can go to the website of the UN department of Economic and Social Affairs and look at their models with different fertility rates. I chose to use the Verhulst curve because it has been around for a while and did not require any assumptions about fertility on my part.

The point of this exercise is that the world population is going to increase and want cheap reliable energy and a standard of living equal to that of the developed world. Therefore, the efforts of Oregon and Corvallis, Oregon, to reduce their carbon footprints are nothing more than noise in the earth's thermodynamic system.

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[5] Figure four was created from United Nations, Department of Economic and Social Affairs, Population Division (2013). World Population Prospects: The 2012 Revision, CD-ROM Edition estimates of world population from 1950 to 2010. The curve was developed by fitting the following equation: $N = C_1 * C_2 *\exp(r*t)/(C_2 + C_1 *(\exp(r*t)-1))$ where N is population, $C_i$ are constants and r is the growth rate. Verhulst first proposed the equation in 1836 (J.D. Murray. Mathematical Biology. Springer-Verlag. 1989).

If we in Corvallis really care about taking a stand on the world's carbon footprint, we must: 1) focus our money and policies on creating and/or developing other energy sources that are just as cheap and reliable as fossil fuels, in order to be a model and give our global neighbors a realistic alternative, and 2) in the meantime, ensure that our Corvallis neighbors do not freeze in the dark because of well-meaning but ineffectual "statement" goals and policies.

## Epilogue

I circulated an earlier version of this paper and received some feedback on my not seeing a world powered by anything but fossil fuels. According to the feedback, a prosperous energy intensive world powered by various clean electricity for most things is possible. Solar, wind, geothermal, hydro and atomic all contribute nothing to greenhouse gases. Moreover, varieties of storage technologies are coming to the market, which will make this not just a possibility, but also a compelling economical choice.

My response is that we will see if and when these new technologies pencil out. However, I do not see these new technologies penciling out for India, China, or Africa soon enough to avoid their extensive use of fossil fuels; but again, we will see.

The feedback went on to ask, that assuming that humans do not choose to go with clean energy, what are my plans for Florida and the coasts of the world? Who pays for the sea walls, who gets them and how long do we defend the coasts? According to the feedback, these are the problems that are appropriately addressed by responsible politicians.

I cannot really answer these questions. However, in my opinion, responsible politicians should minimize any defense of the coasts because defending the coasts is futile. The seaward edge of the continental shelf was the shoreline at one time. Moreover, I expect that much of what is now land on all coasts will become part of the continental shelf. My suggestion is not to buy ocean front property or any land at all in Florida.

January 12, 2020

# HOW MANY PEOPLE CAN THE EARTH SUPPORT?

By John H. Detweiler

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The title of this paper is the same as the title of Cohen's 1995 book[1] because I am trying to deal with the same question, "How many people can the earth support?". Cohen did a very thorough job – in 532 pages – of reviewing the literature and dealing with the question. This paper will be much shorter.

I am trying to deal with the relationship between climate change and the world's people wanting to live as the developed world lives which requires the use of a great deal of energy, much of it carbon dioxide producing, in hopes our politicians can make intelligent choices and not condemn too many people to poverty .

Many people tell us that the climate is always changing -- which is true. However, one thing that has not happened before is the huge human population and that population's dependence on energy.

In this paper I fit three equations modeling population growth to recent United Nations population data and project that growth for 100 years in hopes that politicians trying to deal with climate change think about how many people there are now and how many there may be in the future whose lives depend upon being able to use energy. Revising the title question a bit: "How many people can the earth support living the way the developed world lives?".

The sections of this paper are, in order: summary and conclusions, discussion of the models, the data used, the methods employed, and two appendices.

## SUMMARY AND CONCLUSIONS

The only thing we know for "sure" are the UN data, which are estimates, not a census. The population modeling that I, and others[2], have done are summaries of data and attempts at forecasting, subject to sets of assumptions. They all have to be taken with a grain of salt; at best they make one think about the situation and what may happen.

Given what I read in the scientific literature and popular press, and my modeling, I think we are approaching a limit on the number of people that the earth can support living the way the developed world lives. I expect that the developing world will keep developing as fast as possible because people do not want to live in poverty. I expect the world will slowly shift to non-carbon based energy where possible but will continue using carbon based energy as needed no matter what that does to the climate. And, I expect the changing climate will result in marginal developing countries failing economically, if not being physically destroyed.

I have not discussed pollution and solid waste, including plastics. However, the problems with pollution and solid waste will surely affect the ability of the earth to support an expanding human population.

The best politicians can do is slowly raise the price of carbon, raising it so slowly that it does not force their constituents into poverty. There are many people, whose livelihood depends upon their using large quantities of carbon based fuels,

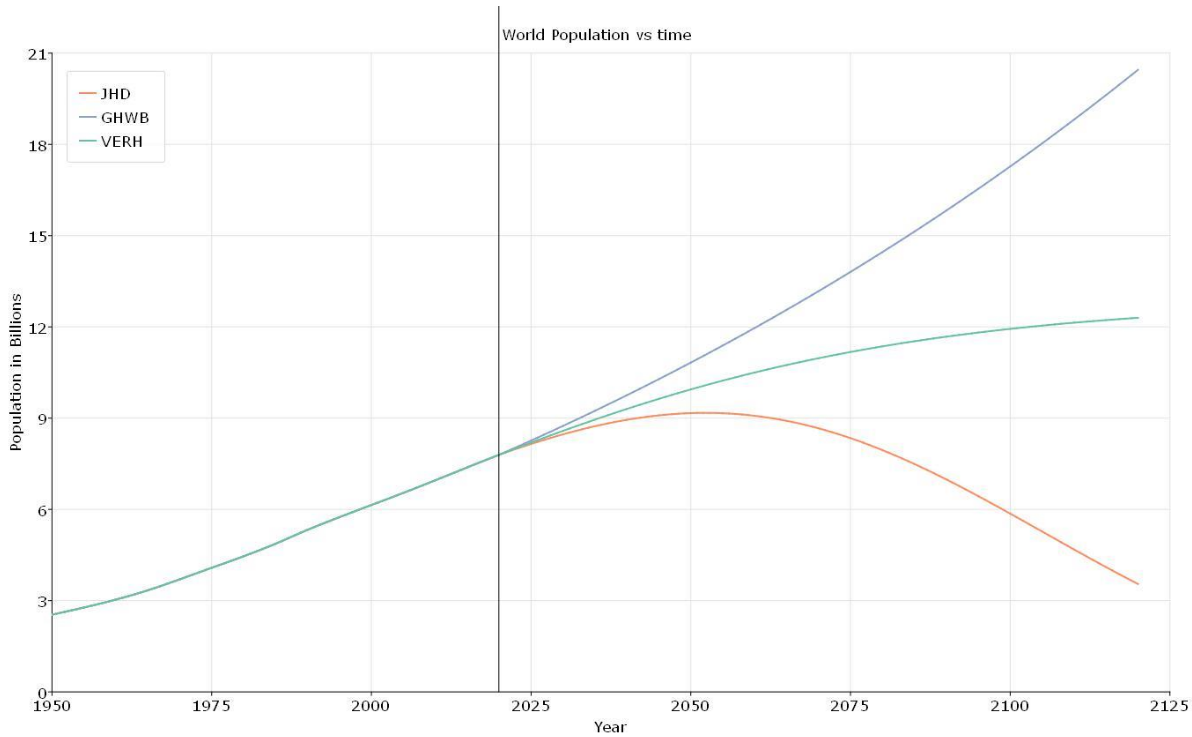
[1] Joel E. Cohen, How Many People Can the Earth Support, W.W. Norton & Company, 1995, 532pp.

[2] See Cohen (1995).

who are more concerned about paying monthly bills than preventing future deleterious changes in the climate. The negative reaction to Oregon's bill HR2020 in 2019 was rural Oregon's resistance to being driven into poverty.

DISCUSSION

The graph below shows the UN data from 1950 to 2020 and a plot of the three equations from 2021 to 2120. The details and logic supporting the equations are discussed in the methods section.




The plot to the left of the vertical line is the plot of the UN data; in 1950 the world population is 2.5Billion people, in 2020 it is 7.8B, over three times as many people. The plots to the right of the vertical line are plots of the three equations. The data plotted is shown in appendix I.

The plot starting at 2020, 7.8B and ending at 2120, 20.5B is the plot of the GHWB equation. If allowed to go on forever, it will go higher forever. Given the problems with climate change, I find it hard to believe that human population can grow without bounds and live the way the developed world now lives. However, reading the popular press, others think this will happen and are acting accordingly.

The plot starting at 2020, 7.8B and ending at 2120, 12.3B is the plot of the VERH equation. If allowed to go on forever, it will asymptotically approach a ceiling of 12.9B. That is easier to believe than the GHWB equation but, again, given the problems with climate change, I wonder if the earth can support 4.5B more people in the fashion the developed world lives.

The plot starting at 2020, 7.8B, rising to a maximum at 2052 of 9.2B and ending at 2120, 3.5B is the plot of the JHD equation. In my opinion, given the problems with climate change, this is a more reasonable forecast than the first two. However, the implication is that we may be coming to the population limit in the near future.

## DATA

The data[3] are File POP/1-1; Total annual populations (both sexes combined) by region, sub-region and country, estimated for the years 1950 – 2020. A description of the data used and the methods applied in estimating past population estimates and demographic changes (fertility, child, adult and overall mortality, international migration) are provided for each country or area. The estimates for each country and area are summed to make the estimate for the world for the period in thousands of people. I used the estimates for the world assuming that there will be no significant migration to or from the world within the next 100 years.

## METHODS

All computations were done with Gauss 19.1[4]; using the Gauss language and application Curve Fit Version 3.1.15 which fits an hypothesized curve to the data minimizing the residual variance with numerical techniques. The three curves I used are described below. The computer printout is shown in appendix II.

In 1991, President George H. W. Bush issued a proclamation recognizing World Population Week stating: "Population growth in itself is a neutral Phenomenon…every human being represents hands to work, not just another mouth to feed."[5] I interpret this to mean that population can grow without bounds coming up with equation 1, the first equation, which I call the GHWB curve.

$$\frac{DP}{dt} = Pr + A \qquad (1)$$

Where: P = population,

r = increase rate,

t= time,

A is a constant[6],

and $\frac{DP}{dt}$ is the rate of change, or first derivative[7], of population with respect to time.

The second equation – equation 2, which I call the VERHULST (abbreviated VERH) curve[8], was hypothesized by Pierre Verhulst, a professor of mathematics in Belgium in 1836. The notion being that a population could only grow so big, it could not grow without bounds.

$$\frac{DP}{dt} = \Pr(1 - \frac{P}{K}) \qquad (2)$$

Where K = is an asymptotic constant.

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[3] United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects 2019, Online Edition. POP/DB/WPP/Rev.2019/POP/F01-1.
[4] Copyright Aptech Systems, Inc. Chandler, AZ USA. 1984-2018. All Rights Reserved Worldwide.
[5] Cohen (1995).
[6] I originally tried this equation with no constant but it did not fit the data at all.
[7] This derivative is a numerical derivative computed from the population data.
[8] Both Cohen (1995) and Murray, J.D. Mathematical Biology, Springer-Verlag, 1989, 767pp. The equation is slightly different in each reference. I used the equation in Murray.

And the other terms are as in equation 1.

The third equation – equation 3, I call the JHD curve because I it made up. The notion being that the world population is larger than it has ever been and starting to bump into limits. The equation models population increasing at a decreasing rate, going to zero and then going negative resulting in a shrinking world population.

$$\frac{DP}{dt} = \mathrm{Pr}(at^2 + bt + c) \qquad (3)$$

Where: a, b, and c are constants.

And the other terms are as in equations 1 and 2.

All three differential equations can be solved for population as a function of time. The solution to equation (2) is the classic logistics equation. I chose to estimate the parameters with the differential equations, because I had less numerical problems estimating the parameters compared to using the population as a function of time. I estimated future populations with the following recursive equation: $P_{t+1} = P_t + DP_t$ Where the terms are as in the above three equations and $dt = 1$.

In equations (1) and (2), the derivative of population is a function of population. In equation (3) it is a function of both population and time.

POP-2019-07-02 OUT 11/25/19 14:43:28
Data in 10^3.

| YEAR | JHD | GHWB | VERH |
|---|---|---|---|
| 1950.0000 | 2536431.1 | 2536431.1 | 2536431.1 |
| 1951.0000 | 2584034.3 | 2584034.3 | 2584034.3 |
| 1952.0000 | 2630861.6 | 2630861.6 | 2630861.6 |
| 1953.0000 | 2677609.0 | 2677609.0 | 2677609.0 |
| 1954.0000 | 2724846.7 | 2724846.7 | 2724846.7 |
| 1955.0000 | 2773019.9 | 2773019.9 | 2773019.9 |
| 1956.0000 | 2822443.3 | 2822443.3 | 2822443.3 |
| 1957.0000 | 2873306.1 | 2873306.1 | 2873306.1 |
| 1958.0000 | 2925686.7 | 2925686.7 | 2925686.7 |
| 1959.0000 | 2979576.2 | 2979576.2 | 2979576.2 |
| 1960.0000 | 3034949.7 | 3034949.7 | 3034949.7 |
| 1961.0000 | 3091843.5 | 3091843.5 | 3091843.5 |
| 1962.0000 | 3150420.8 | 3150420.8 | 3150420.8 |
| 1963.0000 | 3211001.0 | 3211001.0 | 3211001.0 |
| 1964.0000 | 3273978.3 | 3273978.3 | 3273978.3 |
| 1965.0000 | 3339583.6 | 3339583.6 | 3339583.6 |
| 1966.0000 | 3407922.6 | 3407922.6 | 3407922.6 |
| 1967.0000 | 3478770.0 | 3478770.0 | 3478770.0 |
| 1968.0000 | 3551599.1 | 3551599.1 | 3551599.1 |
| 1969.0000 | 3625680.6 | 3625680.6 | 3625680.6 |
| 1970.0000 | 3700437.0 | 3700437.0 | 3700437.0 |
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| 1975.0000 | 4079480.6 | 4079480.6 | 4079480.6 |
| 1976.0000 | 4154666.9 | 4154666.9 | 4154666.9 |
| 1977.0000 | 4229506.1 | 4229506.1 | 4229506.1 |
| 1978.0000 | 4304533.5 | 4304533.5 | 4304533.5 |
| 1979.0000 | 4380506.1 | 4380506.1 | 4380506.1 |
| 1980.0000 | 4458003.5 | 4458003.5 | 4458003.5 |
| 1981.0000 | 4536996.8 | 4536996.8 | 4536996.8 |
| 1982.0000 | 4617386.5 | 4617386.5 | 4617386.5 |
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| 1984.0000 | 4784011.6 | 4784011.6 | 4784011.6 |
| 1985.0000 | 4870921.7 | 4870921.7 | 4870921.7 |
| 1986.0000 | 4960567.9 | 4960567.9 | 4960567.9 |
| 1987.0000 | 5052522.1 | 5052522.1 | 5052522.1 |
| 1988.0000 | 5145426.0 | 5145426.0 | 5145426.0 |
| 1989.0000 | 5237441.6 | 5237441.6 | 5237441.6 |
| 1990.0000 | 5327231.1 | 5327231.1 | 5327231.1 |
| 1991.0000 | 5414289.4 | 5414289.4 | 5414289.4 |
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| 1994.0000 | 5663150.4 | 5663150.4 | 5663150.4 |
| 1995.0000 | 5744213.0 | 5744213.0 | 5744213.0 |
| 1996.0000 | 5824892.0 | 5824892.0 | 5824892.0 |
| 1997.0000 | 5905045.8 | 5905045.8 | 5905045.8 |
| 1998.0000 | 5984793.9 | 5984793.9 | 5984793.9 |
| 1999.0000 | 6064239.1 | 6064239.1 | 6064239.1 |

| | | | | |
|---|---|---|---|---|
| 2000.0000 | | 6143493.8 | 6143493.8 | 6143493.8 |
| 2001.0000 | | 6222626.6 | 6222626.6 | 6222626.6 |
| 2002.0000 | | 6301773.2 | 6301773.2 | 6301773.2 |
| 2003.0000 | | 6381185.1 | 6381185.1 | 6381185.1 |
| 2004.0000 | | 6461159.4 | 6461159.4 | 6461159.4 |
| 2005.0000 | | 6541907.0 | 6541907.0 | 6541907.0 |
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| 2012.0000 | | 7125828.1 | 7125828.1 | 7125828.1 |
| 2013.0000 | | 7210582.0 | 7210582.0 | 7210582.0 |
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| 2015.0000 | | 7379797.1 | 7379797.1 | 7379797.1 |
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| 2019.0000 | | 7713468.1 | 7713468.1 | 7713468.1 |
| 2020.0000 | **** | 7794798.7 | 7794798.7 | 7794798.7 |
| 2021.0000 | | 7868739.1 | 7887242.1 | 7875847.1 |
| 2022.0000 | | 7941384.3 | 7980245.7 | 7956426.4 |
| 2023.0000 | | 8012662.0 | 8073812.8 | 8036512.6 |
| 2024.0000 | | 8082499.6 | 8167947.0 | 8116082.3 |
| 2025.0000 | | 8150824.6 | 8262651.7 | 8195112.8 |
| 2026.0000 | | 8217564.2 | 8357930.2 | 8273581.9 |
| 2027.0000 | | 8282645.7 | 8453786.1 | 8351468.2 |
| 2028.0000 | | 8345996.5 | 8550222.9 | 8428751.1 |
| 2029.0000 | | 8407544.2 | 8647244.1 | 8505410.5 |
| 2030.0000 | | 8467216.9 | 8744853.3 | 8581427.2 |
| 2031.0000 | | 8524943.2 | 8843053.9 | 8656782.8 |
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| 2034.0000 | | 8685737.2 | 9141240.9 | 8878709.8 |
| 2035.0000 | | 8734975.9 | 9241843.6 | 8951251.8 |
| 2036.0000 | | 8781921.7 | 9343056.0 | 9023052.2 |
| 2037.0000 | | 8826508.5 | 9444881.7 | 9094097.1 |
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| 2039.0000 | | 8908347.1 | 9650388.1 | 9233870.0 |
| 2040.0000 | | 8945473.7 | 9754076.3 | 9302574.5 |
| 2041.0000 | | 8979991.0 | 9858392.8 | 9370476.8 |
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| 2047.0000 | | 9129178.7 | 10497702. | 9760556.5 |
| 2048.0000 | | 9143916.5 | 10606525. | 9822615.7 |
| 2049.0000 | | 9155640.1 | 10716007. | 9883816.8 |
| 2050.0000 | | 9164310.3 | 10826153. | 9944156.2 |
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| | | | |
|---|---|---|---|
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| 2062.0000 | 9020151.5 | 12201140. | 10600594. |
| 2063.0000 | 8987007.0 | 12320285. | 10649695. |
| 2064.0000 | 8950606.6 | 12440153. | 10697949. |
| 2065.0000 | 8910963.5 | 12560747. | 10745361. |
| 2066.0000 | 8868094.9 | 12682071. | 10791936. |
| 2067.0000 | 8822022.2 | 12804132. | 10837679. |
| 2068.0000 | 8772770.6 | 12926931. | 10882598. |
| 2069.0000 | 8720369.1 | 13050475. | 10926699. |
| 2070.0000 | 8664850.9 | 13174768. | 10969988. |
| 2071.0000 | 8606253.2 | 13299813. | 11012473. |
| 2072.0000 | 8544617.0 | 13425617. | 11054161. |
| 2073.0000 | 8479987.1 | 13552183. | 11095059. |
| 2074.0000 | 8412412.4 | 13679515. | 11135177. |
| 2075.0000 | 8341945.3 | 13807620. | 11174521. |
| 2076.0000 | 8268642.1 | 13936501. | 11213101. |
| 2077.0000 | 8192562.8 | 14066162. | 11250925. |
| 2078.0000 | 8113770.9 | 14196610. | 11288003. |
| 2079.0000 | 8032333.4 | 14327848. | 11324342. |
| 2080.0000 | 7948320.7 | 14459881. | 11359953. |
| 2081.0000 | 7861806.4 | 14592715. | 11394844. |
| 2082.0000 | 7772867.6 | 14726353. | 11429026. |
| 2083.0000 | 7681584.2 | 14860802. | 11462507. |
| 2084.0000 | 7588039.0 | 14996065. | 11495298. |
| 2085.0000 | 7492317.7 | 15132147. | 11527408. |
| 2086.0000 | 7394508.7 | 15269055. | 11558847. |
| 2087.0000 | 7294703.0 | 15406792. | 11589625. |
| 2088.0000 | 7192993.6 | 15545363. | 11619752. |
| 2089.0000 | 7089476.1 | 15684775. | 11649238. |
| 2090.0000 | 6984247.9 | 15825031. | 11678093. |
| 2091.0000 | 6877408.3 | 15966137. | 11706326. |
| 2092.0000 | 6769058.3 | 16108098. | 11733949. |
| 2093.0000 | 6659300.5 | 16250920. | 11760971. |
| 2094.0000 | 6548238.6 | 16394607. | 11787402. |
| 2095.0000 | 6435977.7 | 16539165. | 11813253. |
| 2096.0000 | 6322623.7 | 16684599. | 11838532. |
| 2097.0000 | 6208283.1 | 16830914. | 11863251. |
| 2098.0000 | 6093063.3 | 16978116. | 11887418. |
| 2099.0000 | 5977071.7 | 17126209. | 11911045. |
| 2100.0000 | 5860416.2 | 17275201. | 11934140. |
| 2101.0000 | 5743204.5 | 17425095. | 11956713. |
| 2102.0000 | 5625543.9 | 17575897. | 11978775. |
| 2103.0000 | 5507541.7 | 17727614. | 12000334. |
| 2104.0000 | 5389304.2 | 17880249. | 12021400. |
| 2105.0000 | 5270937.1 | 18033810. | 12041983. |
| 2106.0000 | 5152545.1 | 18188301. | 12062092. |
| 2107.0000 | 5034231.5 | 18343729. | 12081736. |
| 2108.0000 | 4916098.6 | 18500098. | 12100924. |
| 2109.0000 | 4798247.0 | 18657415. | 12119665. |
| 2110.0000 | 4680775.4 | 18815686. | 12137969. |
| 2111.0000 | 4563780.9 | 18974915. | 12155844. |
| 2112.0000 | 4447358.5 | 19135109. | 12173299. |
| 2113.0000 | 4331600.9 | 19296274. | 12190342. |

| | | | |
|---|---|---|---|
| 2114.0000 | 4216598.7 | 19458416. | 12206982. |
| 2115.0000 | 4102439.7 | 19621540. | 12223227. |
| 2116.0000 | 3989209.3 | 19785653. | 12239086. |
| 2117.0000 | 3876990.1 | 19950761. | 12254566. |
| 2118.0000 | 3765861.8 | 20116869. | 12269677. |
| 2119.0000 | 3655901.4 | 20283983. | 12284425. |
| 2120.0000 | 3547182.4 | 20452110. | 12298818. |

APPENDIX II

```
POP-2019-07-01 OUT        11/24/19        16:41:10

GHWB CURVE

dp/dt = p*r+A
starting parameters

     0.020000000
       100000.00

================================================================================
 CurveFit Version 3.1.15                                  11/24/2019   4:41 pm
================================================================================

return code =    0
normal convergence

Number of cases      69

estimated residual variance     6.44366E+07

The covariance matrix of the coefficients is not available

Parameters   Estimates      Gradient
----------------------------------------------
Inc Rate     0.006060  29367.773041
Alfa     45207.261657     -0.007697

Number of iterations    7
Minutes to convergence     0.00000
parameters =
    0.0060599520
       45207.262
Parameter covariance matrix =
   3.8447123e-07       -1.9075673
      -1.9075673        10398325.
Std error =
   0.00062005744
       3224.6433
data variance =    1.5176738e+08
resid variance =        64436563.
'r^2' =       0.57542548



VERHULST CURVE

dp/dt = r*p*(1-p/K)
starting parameters
```

```
     0.020000000
       12000000.

================================================================================
 CurveFit Version 3.1.15                                  11/24/2019   4:41 pm
================================================================================

return code =    0
normal convergence

Number of cases      69

estimated residual variance     2.58886E+07

The covariance matrix of the coefficients is not available

Parameters   Estimates      Gradient
----------------------------------------------
Inc Rate     0.026416    397.163703
Constant 12854590.715059     -0.001193

Number of iterations    11
Minutes to convergence     0.00000
parameters =
     0.026415859
       12854591.
Parameter covariance matrix =
   2.6093493e-07       -136.30510
      -136.30510    8.6118395e+10
Std error =
   0.00051081790
       293459.36
data variance =    1.5176738e+08
resid variance =        25888620.
'r^2' =       0.82941908




JHD CURVE
 dp/dt = r*p*(a*t^2+b*t+c)
starting parameters

     0.020000000
      -2.0000000
      -3000.0000
       12000.000

================================================================================
 CurveFit Version 3.1.15                                  11/24/2019   4:41 pm
================================================================================

return code =    0
normal convergence

Number of cases      69
```

```
estimated residual variance     2.57510E+07

Parameters     Estimates     Std. err.   Est./s.e.  Prob.    Gradient
----------------------------------------------------------------------
Inc Rate        0.000000             .          .        .  184.500000
Alfa           -5.054581             .          .        .    0.000001
Bravo        -867.137873             .          .        .   -0.000000
Charlie     33856.049032             .          .        .    0.000000

Covariance matrix of parameters computed from
cross-product of first derivatives

Number of iterations    13
Minutes to convergence     0.00017
parameters =
   2.8759108e-07
      -5.0545807
      -867.13787
       33856.049
Parameter covariance matrix =
    -0.012854374       -225923.11       -38758208.    1.5132539e+09
      -225923.11   -3.9707302e+12   -6.8119807e+14    2.6596319e+16
      -38758208.   -6.8119807e+14   -1.1686284e+17    4.5627277e+18
   1.5132539e+09    2.6596319e+16    4.5627277e+18   -1.7814460e+20
Std error =
      0.11337713
       1992669.1
   3.4185207e+08
   1.3347082e+10
data variance =    1.5176738e+08
resid variance =        25750987.
'r^2' =       0.83032594
```