Global Warming Chartbook

Last Fifty Years Extrapolated to Next Fifty Years

Robert A Agnew, PhD

raagnew1@gmail.com

raagnew.com

July 2024

Thesis

Global mean temperature is rising relentlessly in tandem with atmospheric carbon dioxide. We must accelerate the world energy transition from fossil fuels to renewables.

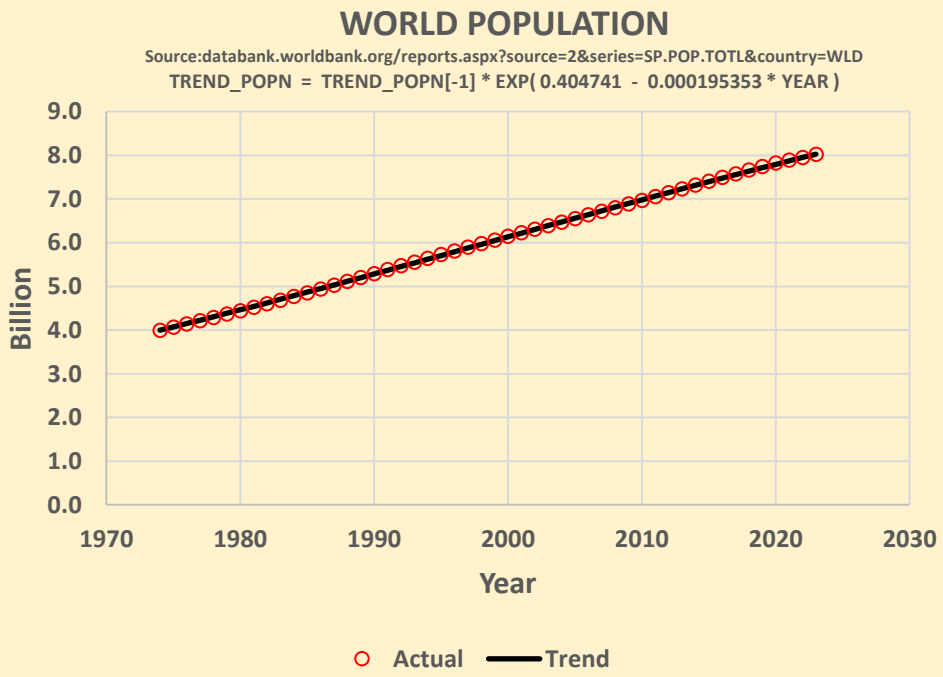
Approach (Updated to 2023)

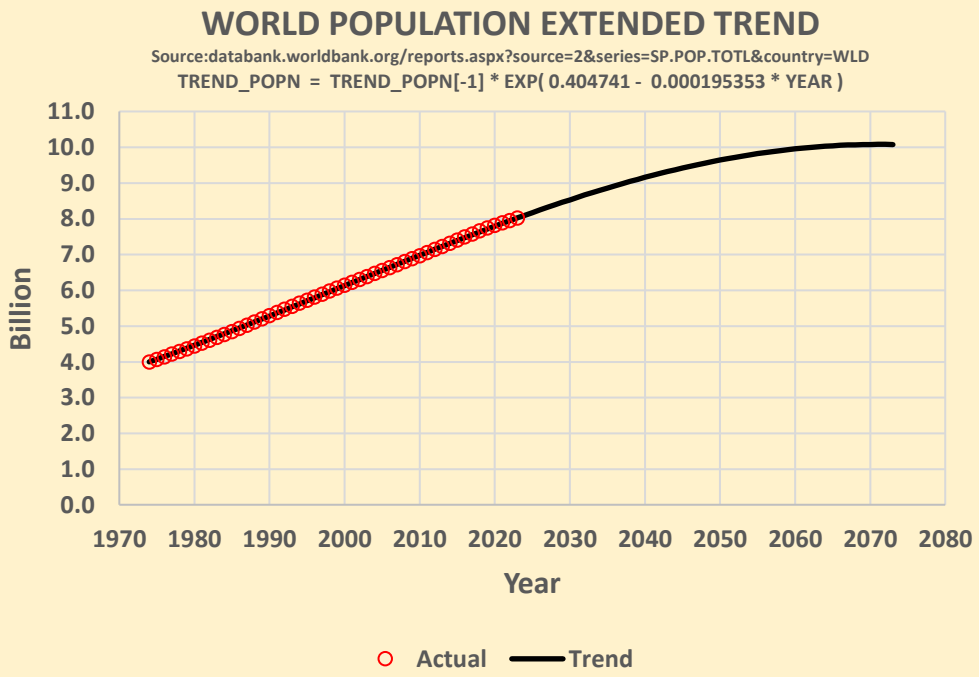
- **Simple trendlines estimated over last 50 years (1974-2023)**
  - **Global Population**
  - **Global Real GDP (2015 US$, Overall and Per Capita)**
  - **Global Atmospheric Carbon Dioxide Concentration (Parts Per Million)**
  - **Global Temperature Anomaly (Degrees Celsius, Relative to 1951-1980 Baseline)**

- **Business-as-Usual Trendlines extended over next 50 years (2024-2073)**
  - **Global population will rise from 8 billion to over 10 billion, peaking in 2071**
  - **Global real GDP will rise from $93 trillion to $251 trillion**
  - **Global real GDP per capita will rise from $11,567 to $24,909**
  - ***But*, global CO2 will rise from 421 PPM to 569 PPM**
  - ***And*, global temperature anomaly will rise from 1.18° C to 2.63° C**

- **Charts illustrate our quandary**

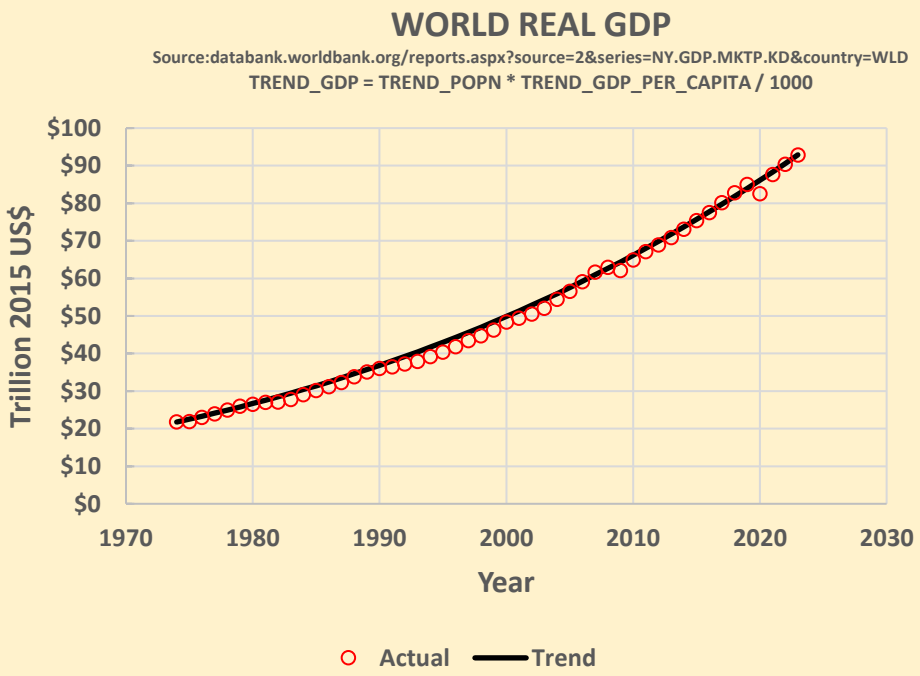
Population peaks over 10 billion in 2071

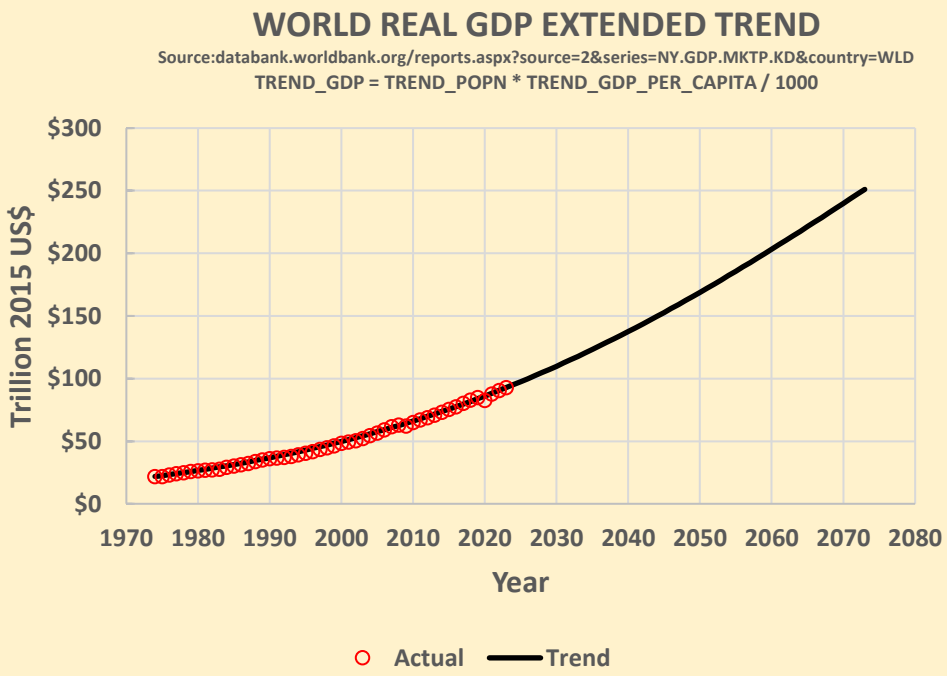




Population has the potential to grow exponentially. However, yearly percentage growth rates have steadily decreased since 1974. Assuming this continues, population will peak in 2071. This is good news although the planet is already overcrowded and new arrivals will want a better life.

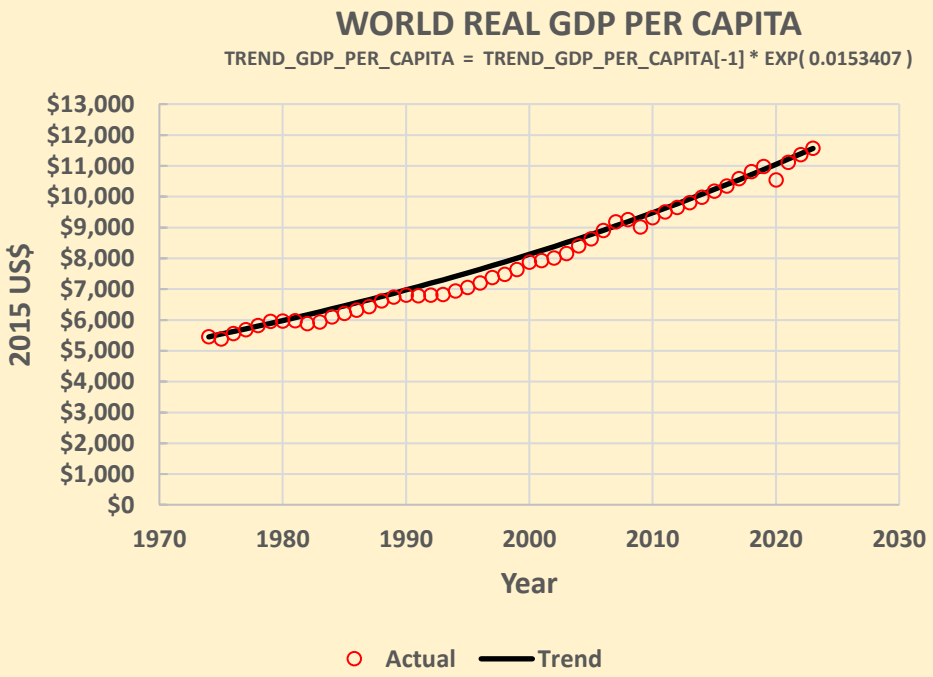
Real GDP exhibits strong growth

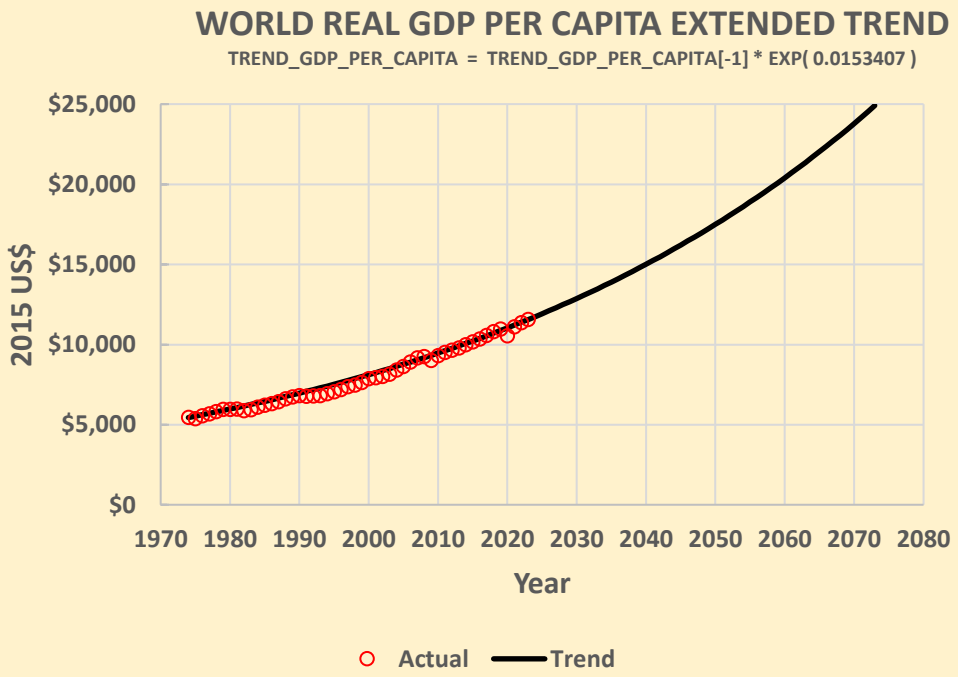




Notwithstanding various economic cycles, including the recent pandemic, world real GDP has followed a remarkably consistent growth path since 1974, largely driven by fossil fuels. However, extension of this trajectory to 2073 is highly questionable in view of environmental impacts.

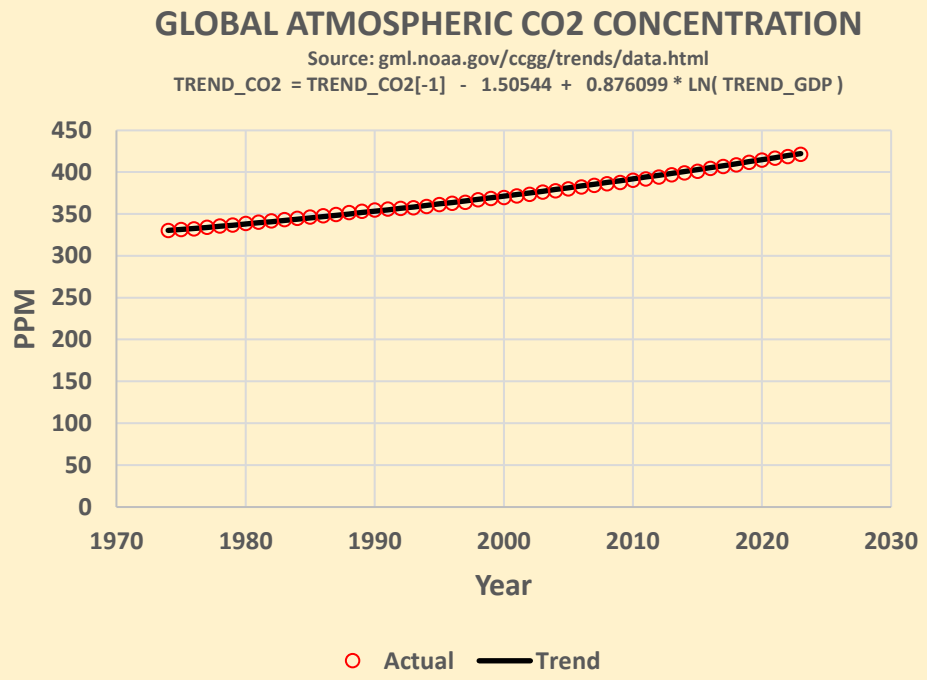
Real GDP per capita more than doubles

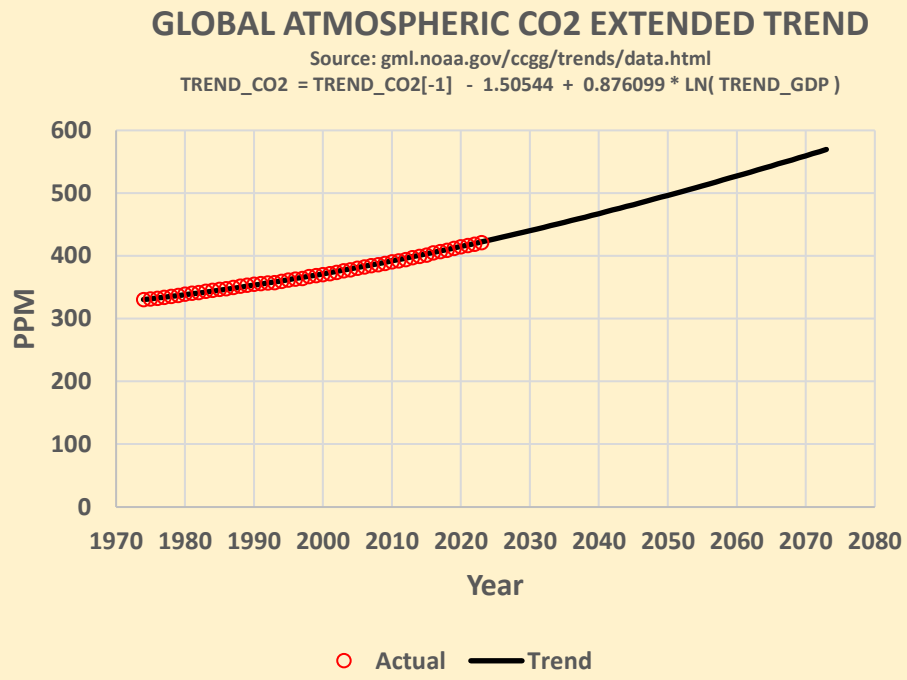




Real GDP per capita grows exponentially at 1.5% per year. This would be great without major environmental degradation! Once again, extension of this trajectory is highly questionable. We need to find a way to uplift the world population without poisoning the atmosphere and frying ourselves.

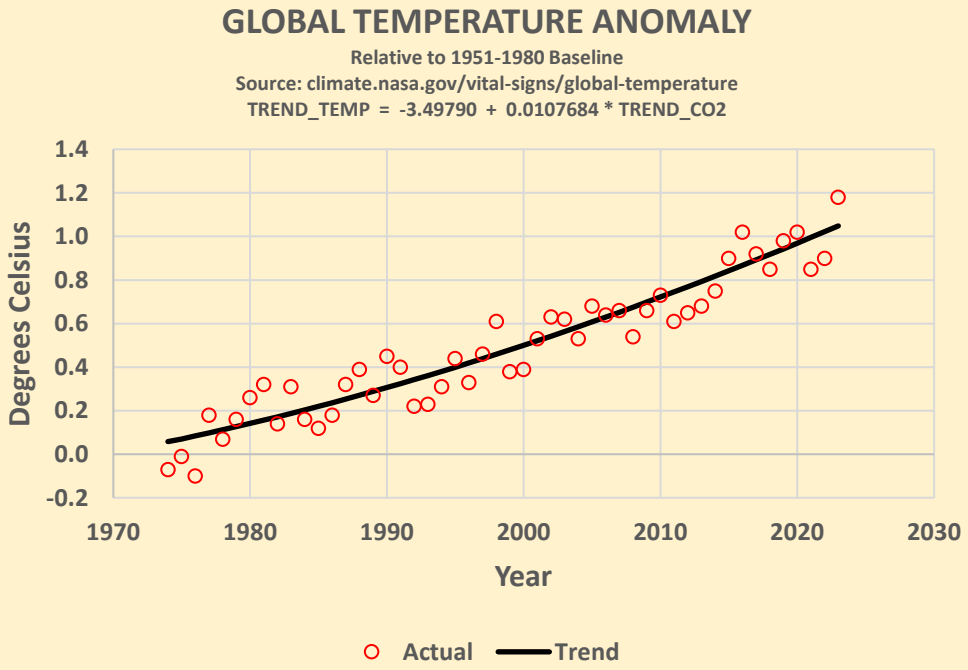
Unfortunately, CO2 increases significantly

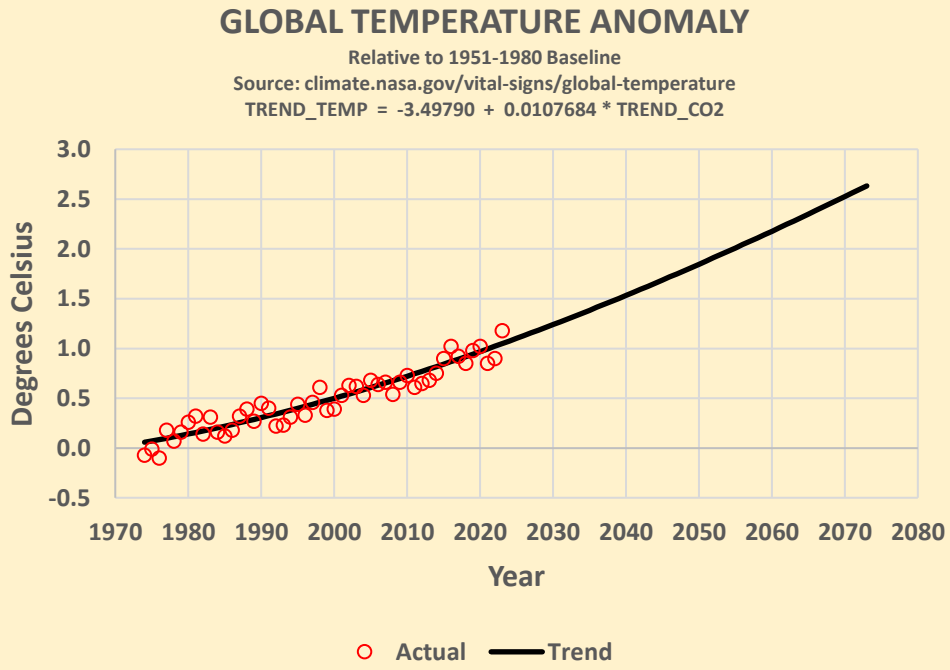




Causal relationships between economic output, carbon emissions, atmospheric greenhouse gas concentrations, and global warming are complex and nonlinear, but they are no longer in doubt. We are already in uncharted territory. Business as usual will make matters worse.

Moreover, temperature increases by 1.5° C





Given everything we're experiencing now (global melt, floods, superstorms, droughts, vast wildfires, extreme temperatures, wildlife extinctions), another 1.5° C is unacceptable. Feedback loops, like permafrost methane release, could accelerate global warming further.

Conclusion

- We can’t allow another 1.5°, or worse, of global warming
- We must accelerate the transition from fossil fuels to renewables
- We must tax bad stuff (fossil fuels, carbon emissions) and fund good stuff (renewables, technological innovation)
- We must cap, and ultimately reverse, atmospheric CO2 concentration
- We must stabilize the Earth’s population, which is already too large
- We must develop the global economy within Nature’s limits
- We are environmental stewards for our descendants
- The future of the planet is in our hands
- Time is of the essence

Statistical Appendix

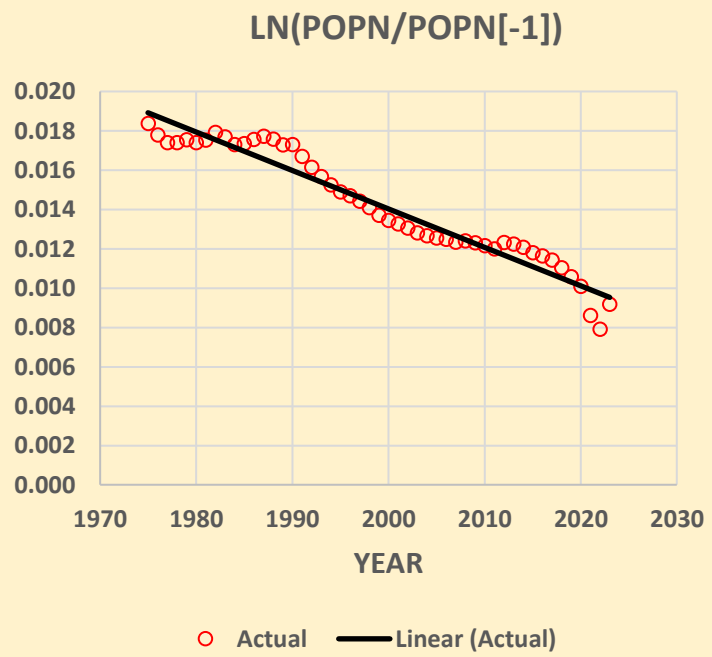
Regression model for LN(POPN/POPN[-1]) vs YEAR

LN(POPN/POPN[-1])	
Regression Statistics	
Multiple R	0.970126466
R Square	0.94114536
Adjusted R Square	0.939893134
Standard Error	0.000705417
Observations	49

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.000373995	0.000373995	751.5776516	1.46571E-30
Residual	47	2.33878E-05	4.97613E-07		
Total	48	0.000397383			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0.404740703	0.014244804	28.41321621	2.99695E-31
YEAR	-0.000195353	7.12579E-06	-27.41491659	1.46571E-30



This model is not perfect but significant linear downtrend is a reasonable basis for extrapolation. Idea here is that annual population growth rate is diminishing over time.

Regression model for LN(GDP_PER_CAPITA/GDP_PER_CAPITA[-1]) vs YEAR

LN(GDP_PER_CAPITA/GDP_PER_CAPITA[-1])

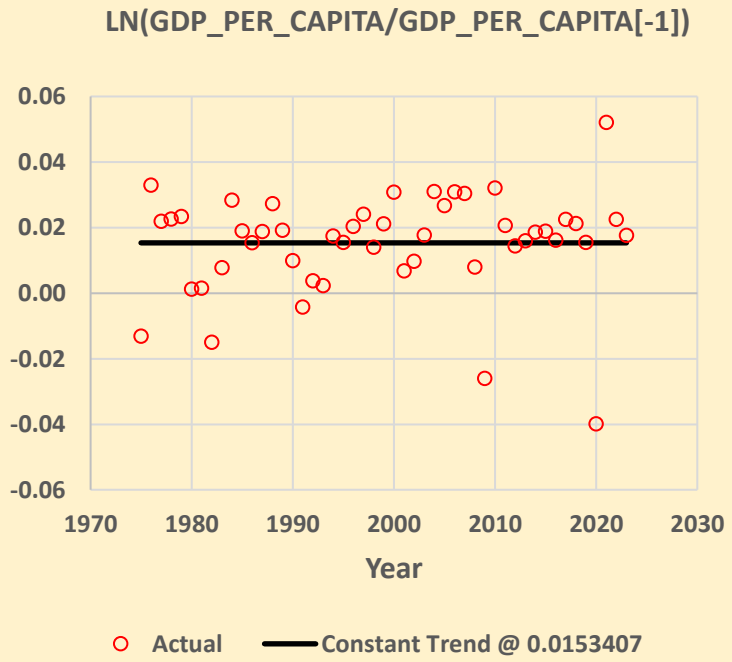
INSIGNIFICANT REGRESSION
USE SIMPLE AVERAGE INSTEAD

Regression Statistics	
Multiple R	0.112268154
R Square	0.012604138
Adjusted R Square	-0.00840428
Standard Error	0.01567954
Observations	49

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.000147498	0.000147498	0.599956437	0.442473975
Residual	47	0.011554855	0.000245848		
Total	48	0.011702353			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-0.22990025	0.316624079	-0.726098428	0.471379012
YEAR	0.000122682	0.000158387	0.774568549	0.442473975



Time-trend is insignificant so we use the simple average for extrapolation. Idea here is that GDP per Capita annual growth rate is constant over time at EXP(0.0153407) – 1 = 1.546%.

Regression model for CO2 – CO2[-1] vs LN(GDP)

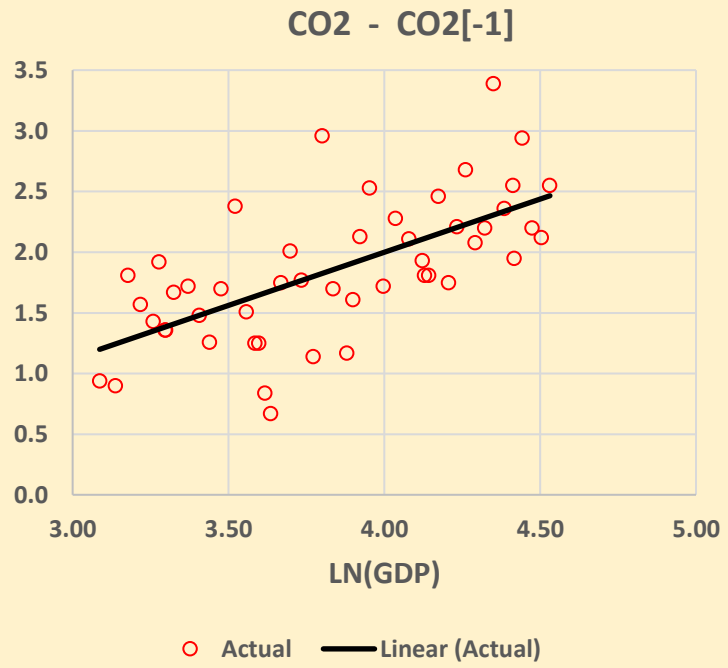
CO2 - CO2[-1]

Regression Statistics	
Multiple R	0.65077171
R Square	0.423503819
Adjusted R Square	0.411237943
Standard Error	0.444090041
Observations	49

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	6.809274178	6.809274178	34.52699283	4.14492E-07
Residual	47	9.269150312	0.197215964		
Total	48	16.07842449			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-1.50544058	0.575386533	-2.6163987	0.011912578
LN(GDP)	0.876099386	0.149098749	5.875967395	4.14492E-07



Volatile scatter but significant uptrend is a reasonable basis for extrapolation. Idea here is that the change in atmospheric CO2 (i.e., annual emission) is nonlinearly related to real GDP, reflecting modest technological efficiencies over time.

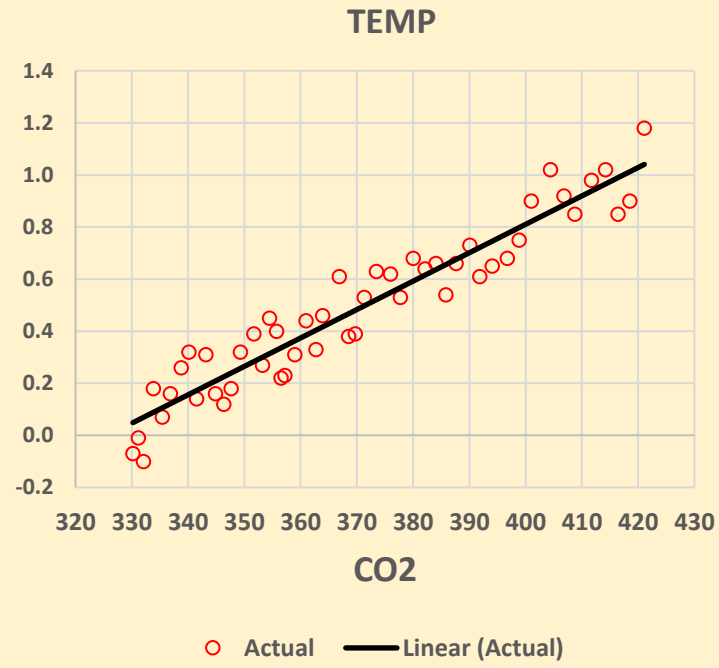
Regression model for TEMP vs CO2

TEMP	
Regression Statistics	
Multiple R	0.951683977
R Square	0.905702393
Adjusted R Square	0.903696061
Standard Error	0.09295188
Observations	49

ANOVA

	df	*SS*	*MS*	*F*	***Significance F***
Regression	1	3.900309391	3.900309391	451.4219795	**9.65909E-26**
Residual	47	0.406082446	0.008640052		
Total	48	4.306391837			

	Coefficients	*Standard Error*	*t Stat*	***P-value***
Intercept	**-3.49789582**	0.188652678	-18.54145856	**2.97813E-23**
CO2	**0.01076838**	0.000506826	21.24669338	**9.65909E-26**



Significant uptrend is a reasonable basis for extrapolation. Idea here is that cumulative atmospheric CO2 has a linear impact on temperature.