Global Warming Chartbook

Last Fifty Years Extrapolated to Next Fifty Years

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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.

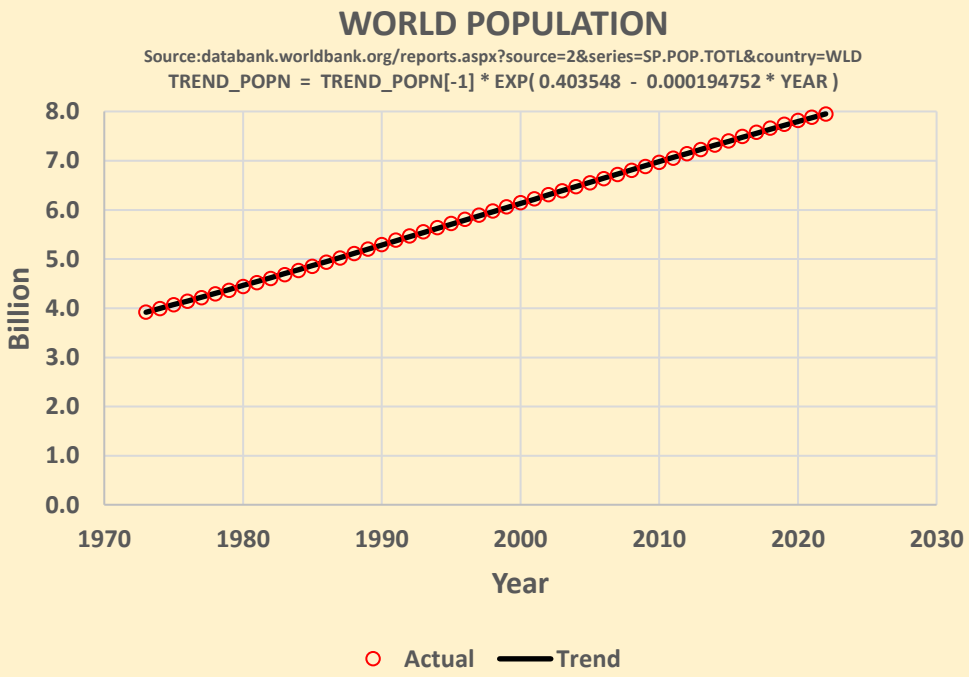
Approach

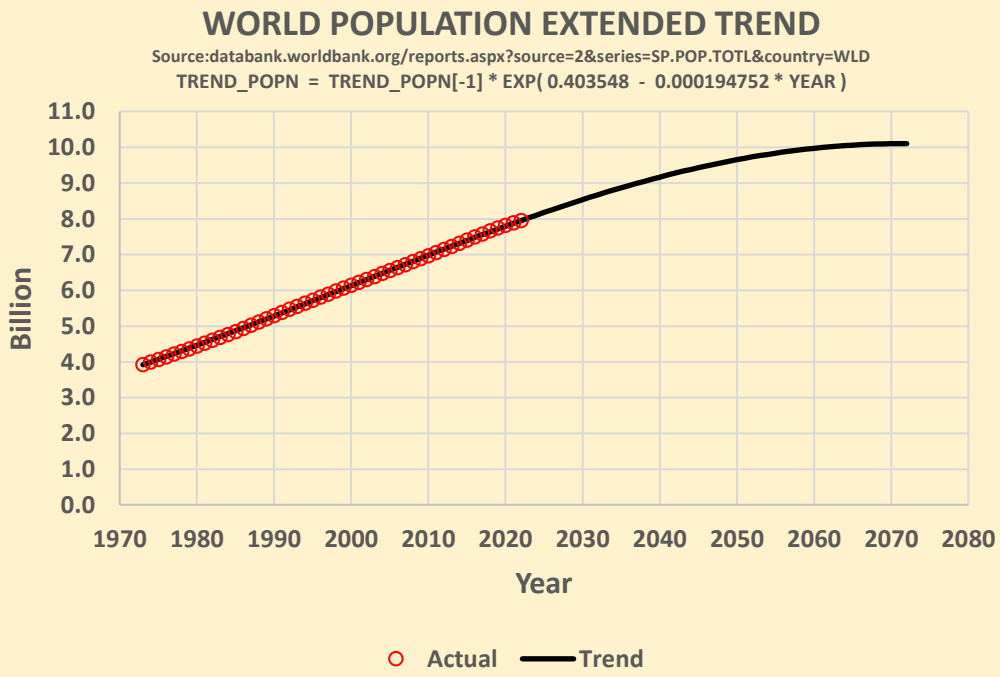
- **Simple trendlines estimated over last 50 years (1973-2022)**
  - **Global Population**
  - **Global Real GDP (2015 US$, Overall and Per Capita)**
  - **Global Atmospheric Carbon Dioxide Concentration (PPM)**
  - **Global Temperature Anomaly (Degrees Celsius, Relative to 1951-1980 Baseline)**

- **Business-as-Usual Trendlines extended over next 50 years (2023-2072)**
  - **Global population will rise from 8 billion to over 10 billion, peaking in 2072**
  - **Global real GDP will rise from $90 trillion to $241 trillion**
  - **Global real GDP per capita will rise from $11,287 to $23,835**
  - ***But*, global CO2 will rise from 419 PPM to 568 PPM**
  - ***And*, global temperature anomaly will rise from 0.89° C to 2.55° C**

- **Charts illustrate our quandary**

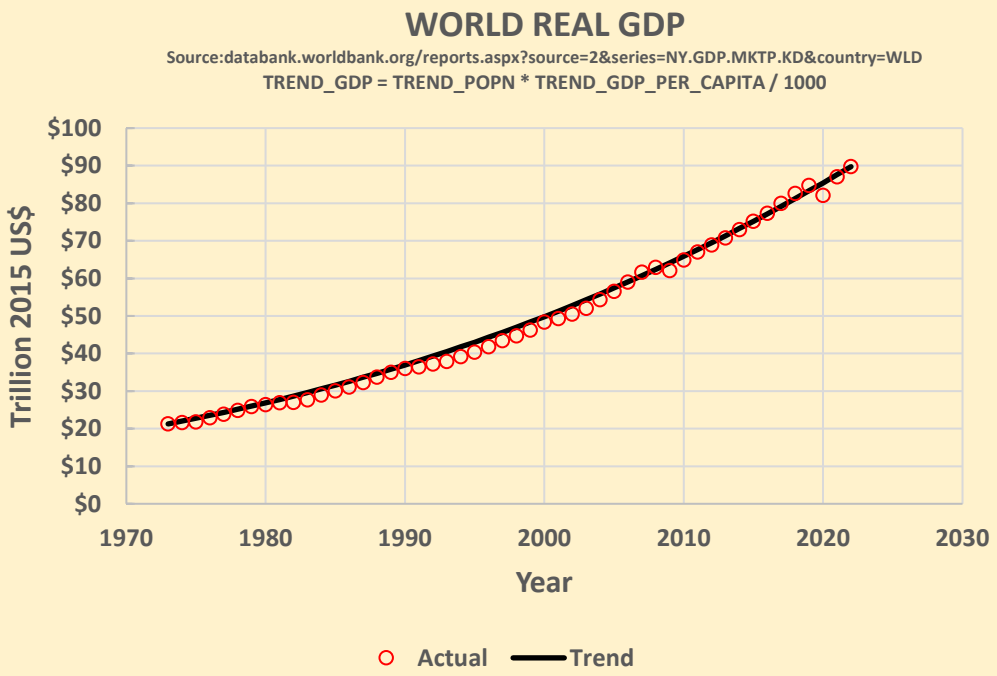
Population grows to 10 billion peak

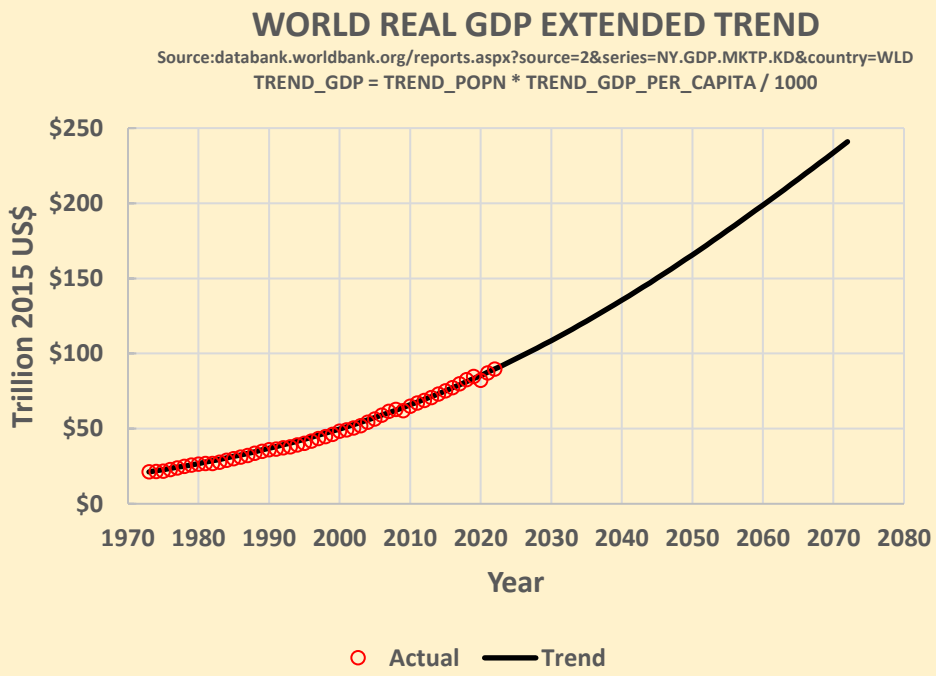




Population has the potential to grow exponentially. However, yearly percentage growth rates have steadily decreased since 1973. Assuming this continues, population will peak in 2072. This is good news although the planet is already overcrowded and new arrivals will want a better life.

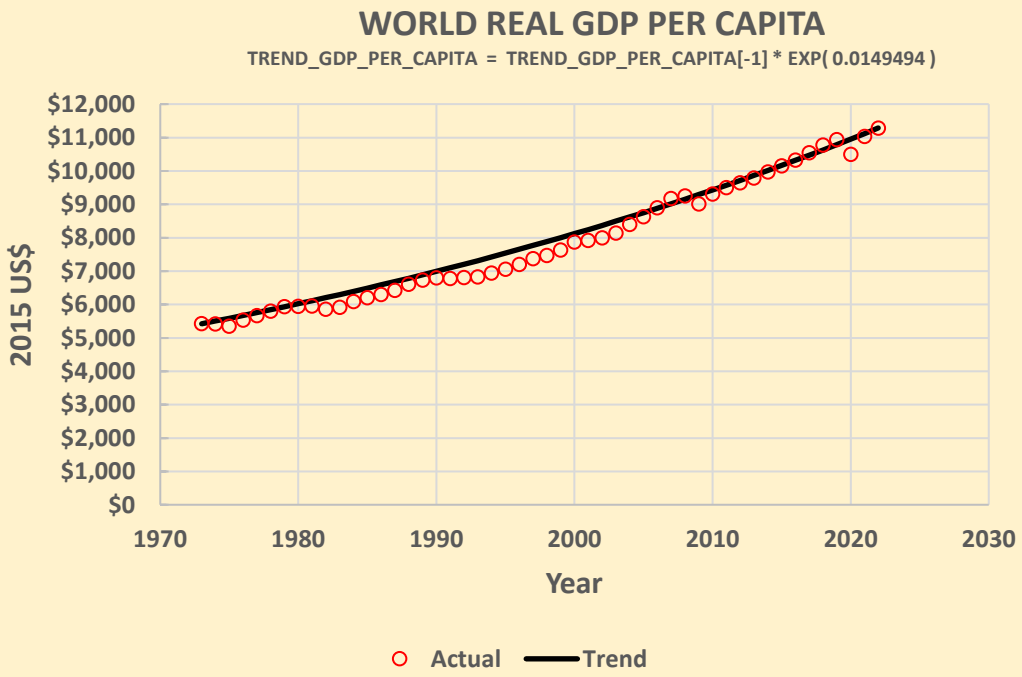
Real GDP exhibits strong growth

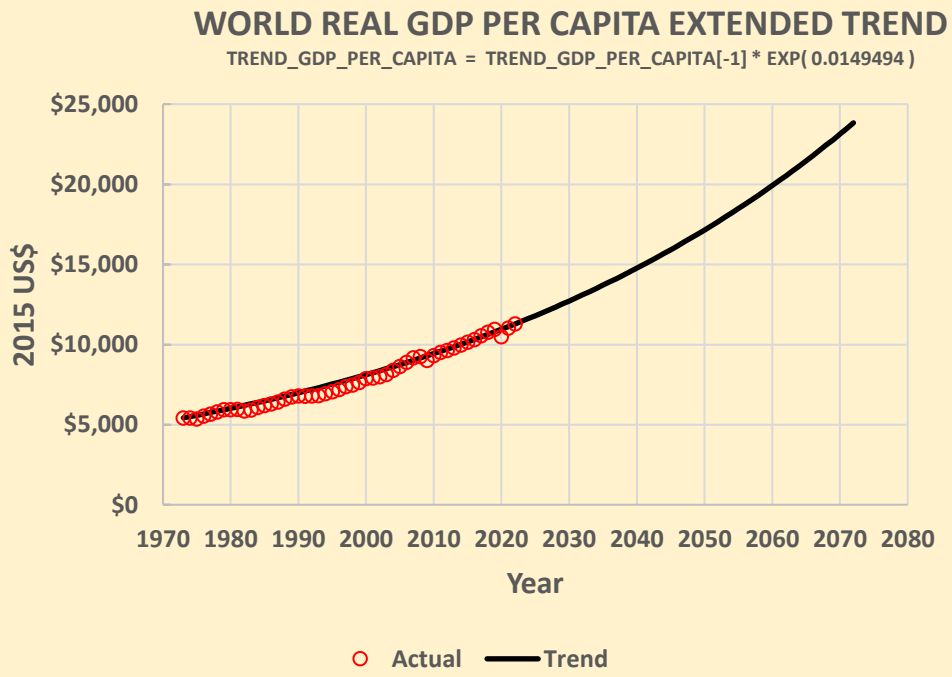




Notwithstanding various economic cycles, including the recent pandemic, world real GDP has followed a remarkably consistent growth path since 1973, largely driven by fossil fuels. However, extension of this trajectory to 2072 is highly questionable in view of environmental impacts.

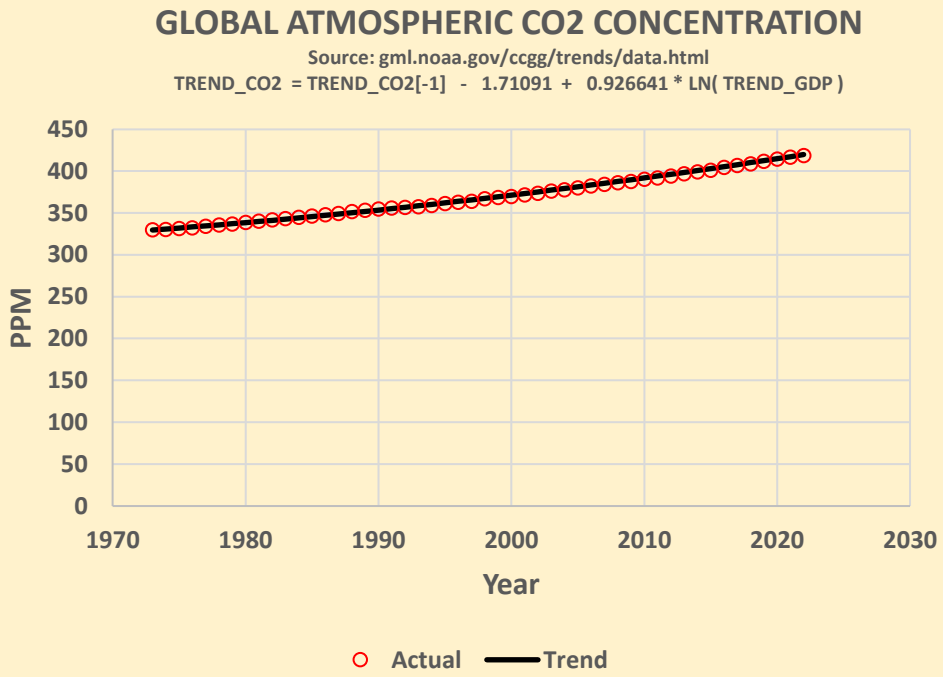
Real GDP per capita more than doubles

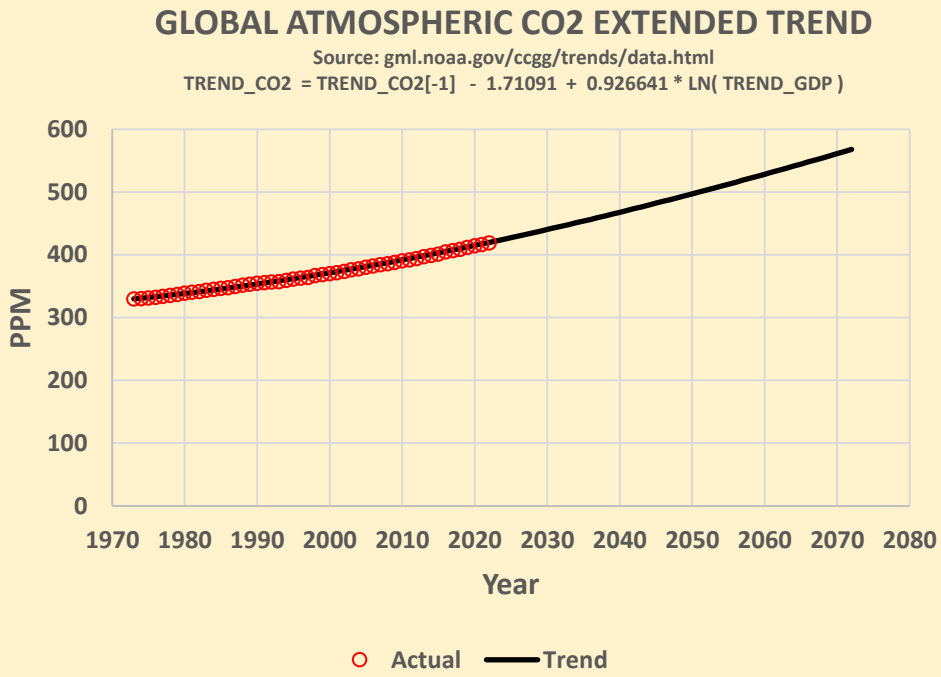




Real GDP per capita grows exponentially at 1.5% per year. This would be great without major environmental degradation! Once again, extension of this trajectory is highly questionable. We need to find a way to uplift the world population without poisoning the atmosphere.

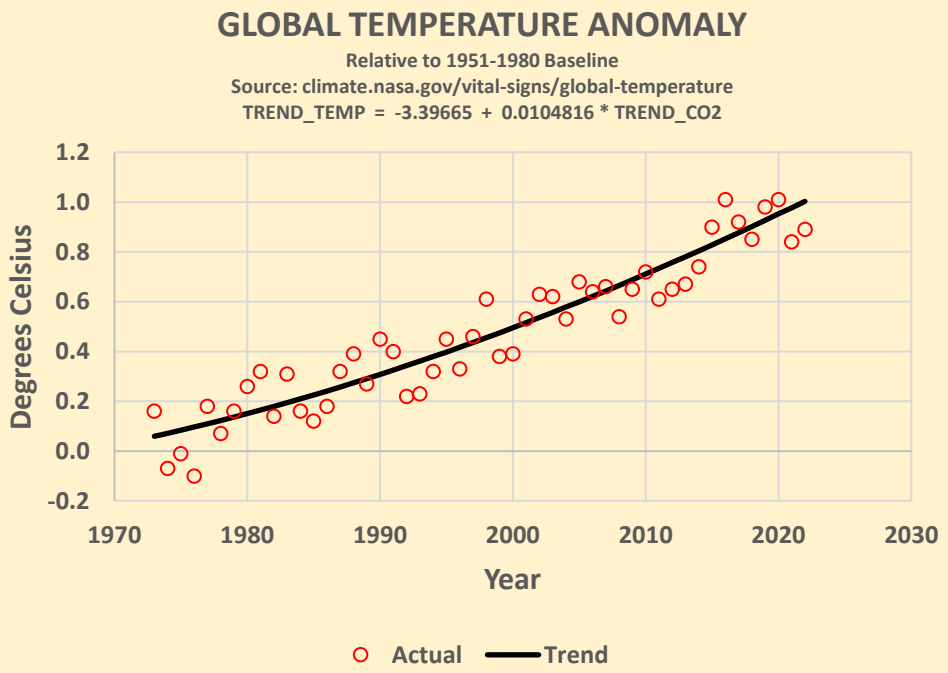
Unfortunately, CO2 increases significantly

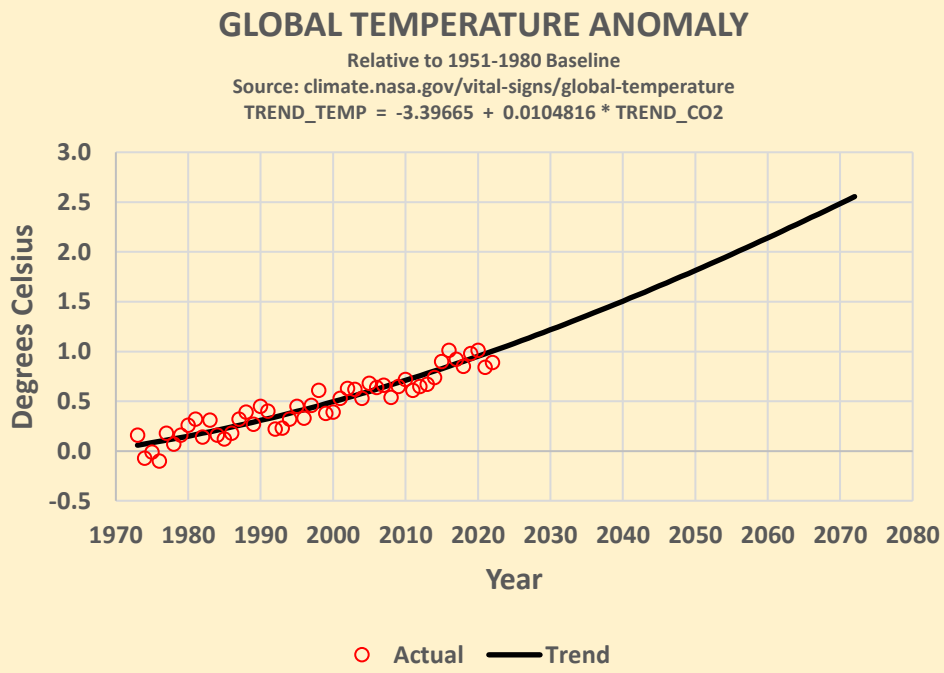




Causal relationships between economic output, carbon emissions, atmospheric greenhouse gas concentrations, and global warming are complex and nonlinear, but they are no longer in doubt. We are already in uncharted territory. Business as usual will make matters worse.

Moreover, temperature increases by 1.7° C





Given everything we're experiencing now (global melt, floods, superstorms, droughts, vast wildfires, extreme temperatures, wildlife extinctions), another 1.7° C is unacceptable. Feedback loops, like permafrost methane release, could accelerate global warming further.

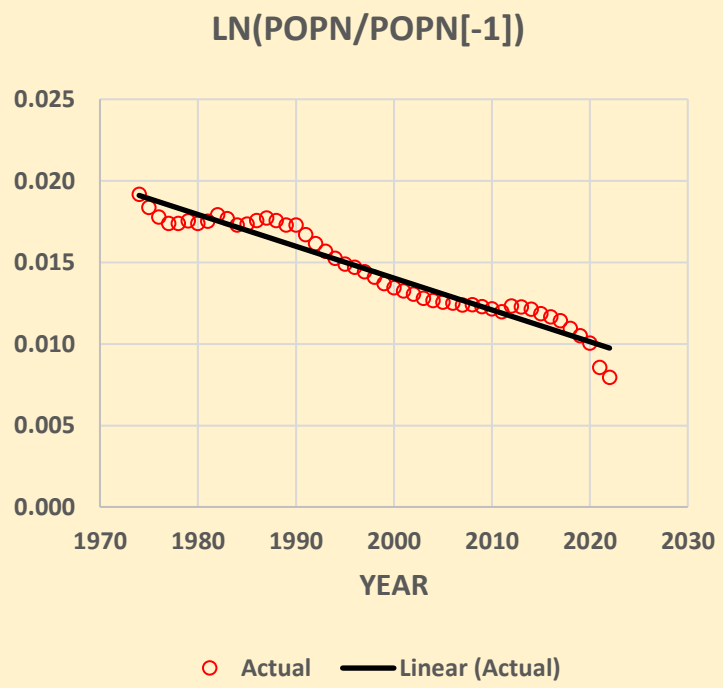
Conclusion

- **We can’t allow another 1.7°, 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

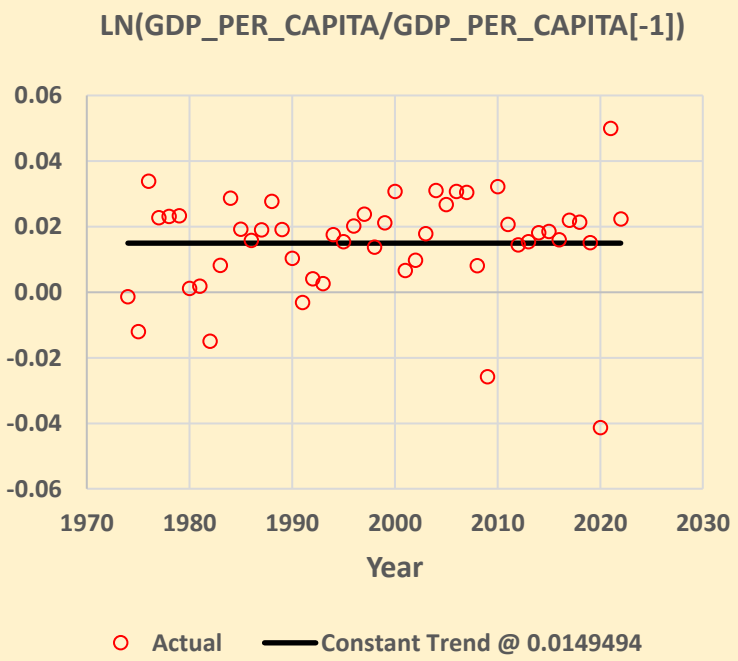
LN(POPN/POPN[-1])					
Regression Statistics					
Multiple R	0.969993677				
R Square	0.940887733				
Adjusted R Square	0.939630025				
Standard Error	0.000704881				
Observations	49				
ANOVA					
	df	SS	MS	F	Significance F
Regression	1	0.000371698	0.000371698	748.0972296	1.62436E-30
Residual	47	2.33523E-05	4.96858E-07		
Total	48	0.00039505			
	Coefficients	Standard Error	t Stat	P-value	
Intercept	0.403547693	0.014226871	28.36517459	3.23115E-31	
YEAR	-0.000194752	7.12038E-06	-27.35136614	1.62436E-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

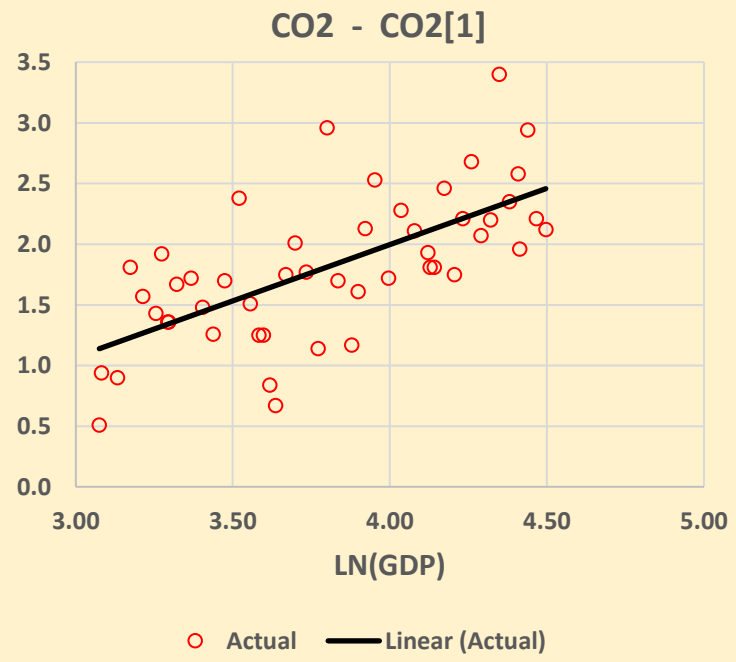
LN(GDP_PER_CAPITA/GDP_PER_CAPITA[-1])			INSIGNIFICANT REGRESSION		
			USE SIMPLE AVERAGE INSTEAD		
Regression Statistics					
Multiple R	0.121324872				
R Square	0.014719725				
Adjusted R Square	-0.00624369				
Standard Error	0.015772064				
Observations	49				
ANOVA					
	df	SS	MS	F	Significance F
Regression	1	0.000174669	0.000174669	0.702162701	0.406299182
Residual	47	0.011691626	0.000248758		
Total	48	0.011866295			
	Coefficients	Standard Error	t Stat	P-value	
Intercept	-0.25179161	0.318333141	-0.790968885	0.432935556	
YEAR	0.000133504	0.000159322	0.837951491	0.406299182	



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(0.0149494) – 1 = 1.5%.

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

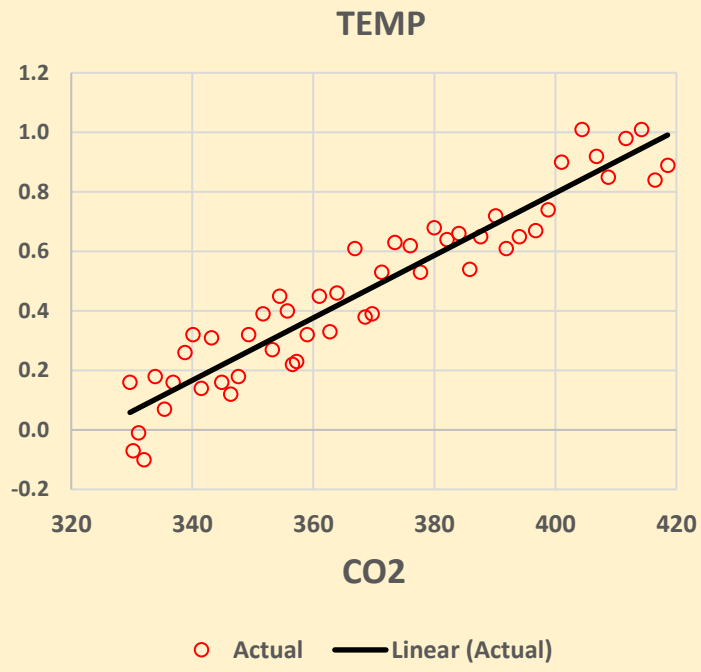
CO2 - CO2[-1]					
Regression Statistics					
Multiple R	0.663971431				
R Square	0.440858061				
Adjusted R Square	0.428961424				
Standard Error	0.454848416				
Observations	49				
ANOVA					
	df	SS	MS	F	Significance F
Regression	1	7.666690828	7.666690828	37.0573685	1.98419E-07
Residual	47	9.723692845	0.206887082		
Total	48	17.39038367			
	Coefficients	Standard Error	t Stat	P-value	
Intercept	-1.71090814	0.582690353	-2.936221838	0.005129572	
LN(GDP)	0.926641113	0.152220897	6.087476365	1.98419E-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	0.949157842				
R Square	0.900900609				
Adjusted R Square	0.898836038				
Standard Error	0.092843508				
Observations	50				
ANOVA					
	df	SS	MS	F	Significance F
Regression	1	3.761405987	3.761405987	436.3622074	9.69332E-26
Residual	48	0.413756013	0.008619917		
Total	49	4.175162			
	Coefficients	Standard Error	t Stat	P-value	
Intercept	-3.39664632	0.18544285	-18.31640484	2.67014E-23	
CO2	0.010481561	0.000501767	20.88928451	9.69332E-26	



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