A response to the Hanley submission critique of the Tim Garrett et al (GGK22) Paper "Lotka's Wheel and the Long Arm of History

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I've done an independent investigation into the validity of the GGK22 and prior work on what I've come to call the "Power/Wealth Relation" (P/W); i.e. the constancy of the ratio of the inflation corrected sum total of all human production, and the current consumption rate of primary power. I can confirm that the PW relation is indeed essentially a constant over the period since 1970 - when yearly global data become available in the literature. I won't repeat Garrett's own criticisms of Hanley's contentions here, but I too find Hanley's contentions just as puzzlingly unsupported and unsupportable. I don't have any disagreements with Garrett's points. I'll say too, that I've never met Tim Garrett, and we have no professional or personal relationship. I'm intrigued by this work; that's my connection, and my interest is its connection to related work I do for the Earth Futures Institute at UCSC.

My interest is whether the P/W relation can be expected to remain valid, and whether it may even be an inevitable feature of human civilization's evolution. If so, it should be part of any integrated assessment modelling by economists in forecasting future outcomes of different realistic climate policy. I've done my own investigations and public lectures on this subject, and the results are consolidated in Presentations, including this longest version **here.** I'll refer to it below.

1. **Adding the Shadow Economy:** The thermodynamic arguments that this relation is reasonable and should not be unexpected, should rightfully include not just the denominated wealth in monetized transactions, but also the "shadow economy" of barter etc. The most complete work I've found on the size of the shadow economy, as of a few years ago, is from Elgin and Oztunali (2012). They find that the shadow economy has been a slightly declining ~23% fraction of the visible economy since 1970 (see slide #291). This slightly declining fraction, when incorporated into the Wealth and into P/W relation, actually improves the constancy of that relation.

2. **The P/W Constancy over different time scales:** One might wonder whether 1970-> present is long enough. Garrett makes a strong case that there has been large changes in energy and economic factors during that period and yet the constancy is quite impressive. If the P/W relation is valid even for short time scales, it imposes constraints on how energy efficiency should behave during recessions. I find that

data from the Federal Reserve supports the contention that even during shorter time scales of a year or two, that the P/W relation is obeyed better than the data suggests (which uses just the official figures for GDP). (see slide #295). There is a "Recession / GDP Bias" which over-estimates GDP during recessions and underestimates a bit in post-recession (slides #309-310). It is seen in the two largest economies in the world, and shows that energy efficiency actually stops improving and goes into reverse during recessions, and the economic motivations that this should be true are fairly easy to appreciate – energy efficiency investment is the least important thing to be funding when you're in economic contraction; far more demandingly immediate is preserving (against 2nd Law of Thermodynamics decay) what has already been created, and then in developing new energy to support that preservation, and then if possible, expansion of energy access, and only after that spending is done, does investment in improving energy efficiency pencil out. Why? Because investment in improving energy efficiency only pays off in the future, which is discounted rather strongly by economic policy people advising corporations and government. Historically, globally we have improved energy efficiency of GDP by 1.1% per year, but that only makes profit sense if we can achieve an ROI of 2.2% year growth in GDP. When GDP goes into recession, then energy efficiency, according to the P/W Relation, must reverse. A closer look at the data (slides #93-#97) shows that indeed it does (slides #309-311).

3. **The PPP vs MER argument:** I'm in agreement with Garrett that MER is the proper method to calibrate between currencies. PPP is not. To use the "Big Mac Index" metaphor; that Big Mac has more capacity to improve labor production when in a country with stronger networks supporting that civilization, than in a poorer country. It's not just the income base that is the issue, it's the ability of that Big Mac to fuel production. Currency traders put money on the line, and are the more properly motivated actors to do the job correctly. Over very short terms, of course, traders' profit concerns can dominate, with resulting volatility, but averaged over a ~year, MER will be the more defensible measure of the calibrated value of a currency. The data show that MER accounting shows slower economic growth among poorer countries than PPP accounting does, and this means that the energy efficiency improvements globally are not as impressive as PPP accounting would suggest (slide #307). This may be inconvenient to some. But more to the point, one can argue that the PPP vs. MER debate is not relevant for criticizing the P/W Relation. If the P/W Relation is obeyed only with MER accounting, so be it.   Further, if P/W isn't obeyed with PPP accounting, where instead it shows a slope, then this just might be a sign that it is PPP accounting that is flawed... if, as physicists do, we take observational patterns as trying to tell us of important truths we may not yet

appreciate, and which may contradict our ideology or assumptions, and so we should pay closer attention.

4. **Inflation measure:** Garrett uses the standard published dGDP (GDP deflator) inflation adjusted figures. But there is much debate about the way economists have chosen to re-define CPI and hence dGDP inflation with a change in method in the mid 1990's, and in a way which underestimates true inflation (slides #266-277) arguably for political reasons as pointed out by many. I've chosen to use the MIT's "Billion Prices Project" work to adjust dGDP, as a fairer measure (slide #283). When I do so, the P/W Relation is not only still supported, it is a bit better supported in its constancy.

5. **Civilization Obeys Thermodynamic Laws**: That human civilization systems obey thermodynamic laws is even more strikingly confirmed by the work of Victor Yakovenko (see slides #15-24 in this Presentation, with links to his publications) with the demonstration of the Boltzmann-Gibbs distribution of incomes, the close parallel of "income" with thermodynamic "temperature" and implications for entropy evolution and the Gini Coefficient in civilization's economic systems.

6. **Thermodynamics and Human Agency:** Finally, economists have, over the years, shown an antipathy with any connections with thermodynamics. Given Neoclassical ideology, a plausible explanation for this attitude is because it casts doubt on the belief in an ultimate free will and primacy of human agency. Neoclassical theory maintains that innovation and price change will always find a way to keep economic growth moving forward. Physicist Geoff West has shown this is not true ("Scale"), that cycles of innovation have their own entropy penalty to them, and these will outrun the ability for more and more rapid innovation to stave off collapse and decay (slides #52 to 58 in this Presentation).

I do have a couple of places where I disagree with Garrett's work; Garrett maintains there is an intimate cause/effect relation between economic inflation and energy return on energy invested. But economic inflation is governed more powerfully by the actions of central banks, who control short term interest rates motivating the large banks to create or reign in money creation via "loans". These decisions can be subject to questionable political decisions or mis-readings of a crisis (e.g. the CoVid recession caused a large over-reaction by the Federal Reserve who then multiplied the money supply; an error we're all paying for today in high inflation). I believe the relation between inflation and EROI is not as close as Garrett maintains. One can imagine that worsening EROI could just be ignored by the money suppliers and so that energy costs would go up, requiring other prices to go down due to unaffordability in a worsening recession. Garrett has speculated in the past (I'm not sure his present thoughts on this) that it is reductions in energy efficiency which cause

recessions. I disagree with this, and in fact it is much easier to see the logic that cause-effect goes the opposite direction, as described above. Recessions can have a variety of causes; disease pandemics, wars, poor policy decisions, bad allocations by markets in search of short term profits... but the resulting recession will affect how money is then allocated, such that improving energy efficiency now takes a back seat to dealing with more pressing needs. However, these points do not affect the validity of the P/W Relation's validity in the data, which was the subject of Hanley's critique. These points only relate to how to interpret what the P/W Relation's origin is, and its ultimate meaning.

My investigations into the P/W Relation are not published except in talks and Presentations I've given. A more compact and newer Presentation on this is here. It's been clear that conventional economists do not like to think of this relation as being true. For one, it says that to reduce energy consumption requires a long term economic recession or depression; a decision to let go of supporting civilization's growth. This is utterly antagonistic to the goal of economists – to promote and guide how to achieve maximum economic growth. There's clearly no hope of getting work such as I've done published in an economics journal. However, my talks have not had any substantive criticisms or refutations of the evidence and reasonings.

Richard Nolthenius – Apr 7, 2025