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Discussions

Interactive comment on "Long-run evolution of the global economy: 2. Hindcasts of innovation and growth" *by* T. J. Garrett

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Review by Peter Haff

I am greatly appreciative of Prof. Haff's thoughtful review of the paper and his helpful summary of its contents. There were a few questions in the review that are addressed below.

Possible points that may profit from more discussion in Garrett's paper include the observed constancy of the proportionality factor between power usage and accumulated wealth of civilization. A general correlation between these two quantities is not surprising, but the reasons for a rigid constancy are less clear.

A more detailed discussion of the physical motivation for presuming the relationship between a and C is outlined in Section 2 and Appendix A (of the revised document, Part 2.1 of the discussion document), and in much more detail in Part I. The basic interpretation is that wealth is a manifestation of reversible circulations within civilization, and these are sustained by a proportionate degree of energy consumption. Of course, this does not provide a mechanistic explanation for how our neurological perception of financial worth relates to a capacity to dissipate energy. This is an interesting challenge that may form a line of future work. The interpretation that is provided might be debated. What matters most is that wealth *as defined* has a fixed relationship to energy consumption that is supported by available data.

A second point that might be developed in more detail is the assumption that each unit of reserve energy consumed by civilization will be used to expand civilization's "boundary" with the source of such reserves. Garrett does not provide a physical argument for this assumption, but the suggestion seems to be that even "nonproductive" consumption of energy, like playing video games (my example), increases the highly filigreed contact boundary, in this case as expressed in an increased number of energy-using play stations and other gaming hardware. In any case, a short explanation would be in order here.

The physical argument that is provided is that energy consumption only goes towards expanding the boundary if there is an imbalance in the energetic flows as described in Appendix A (Part 2.1 of the current document). In this case energy consumption is faster than energy dissipation. Nearly all of energy consumption is required to sustain wealth, or the magnitude of civilization circulations that has previously been accumulated through a past energetic imbalance driving material growth. A much smaller fraction goes towards further expansion, currently at a rate of about 2.2% per year. The text now includes the following paragraph

From Part 1, and as illustrated in Fig. 2, civilization can be thought of as a heat engine where energetic and material flows are coupled. Increasing energy consumption in Eq.

3 arises where civilization is able to incorporate matter into its structure faster than it decays. Civilization is made of matter not energy, but as it grows it increases a material interface with available energy reserves. In the material growth phase it also consumes more energy with time.

Finally, it would also be useful to compare the basic datum used here that, as a function of time, global energy usage is proportional to accumulated GWP, to the results of Brown et al (listed in Garrett's references) that per capita energy usage is proportional to a power (roughly 3/4) of per capita GDP as calculated from a time average of data for individual countries.

Yes, this is certainly an intriguing result. One aspect of this work that remains to be developed further is the relationship of macroscopic economic variables to more internal quantities such as people. It is beyond the scope of this particular paper but the goal is to address it in future development of the implications of underlying theory.

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