Review of: "A Law for Irreversible Thermodynamics? Synergy Increases Free Energy by Decreasing Entropy"

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Terms used here

kB is the Boltzmann's constant

T is the temperature.

Introduction

I see difficulties when well-defined terms in the natural sciences are used outside their normal sphere of use. So it needs to be clear whether a term is being used strictly in its scientific sense or is used as an analogy. But care is needed, because relationships implied by the analogy may not hold.

For example, the term equilibrium in the natural sciences refers to the stable state which an isolated system, (or complex system) settles in for most of the time. Following a disturbance, the system again returns to the equilibrium state.

On the other hand, the equilibrium in neoclassical economics is a different concept. It is a homeostatic state far from the thermodynamic equilibrium of physics. In the neoclassical equilibrium, economic forces balance, allowing markets to clear, for supply to equal demand at a particular price and so on. This so-called economic equilibrium behaves differently, as a shock, such as a short term price rise for oil, usually shifts the economy to a different long term state (See Devine, An economy viewed as a far-from-equilibrium system from the perspective of algorithmic information theory. https://doi.org/10.3390/e20040228)

Similarly for energy and work. A person chopping wood does work in the physics sense. This work is possible because free energy is in the food consumed by the wood chopper to provide the energy for the work. The output can be related to the free energy input.

However, a person tapping on a keyboard is does very little work, even though they might be productive. There is no relationship between the free energy in the food of the typist and the output of the typist's activity.

In science, entropy can mean the entropy of thermodynamics, or the entropy of Shannon's information theory or that of algorithmic information theory. In many natural systems these can be related. The entropy of an economic network, can be articulated in Shannon terms, but in this case it is not simply related to thermodynamic entropy (e.g. Hausseman et al. (2011)). However, one can say that the lower the entropy of such a network, the more ordered its structure compared with a random network.

Similarly, the information of Shannon's information theory, is not the same as negentropy, but may be able to be related in certain well-defined systems.

I find it difficult to see what the paper is trying to say, as words like entropy, free energy are not defined or explained sufficiently well. Let me work through some of the issues in more detail.

The Title of the paper is problematic

Depending on how these terms are defined, something like synergy might increase free energy and decrease entropy. However, from the examples given, it is not even plausible to suggest this observation is a law of thermodynamics, as it is unclear when these concepts are even used thermodynamic sense. If not, they are at best analogous to, but not identical with the thermodynamic terms.

Entropy and synergy

Febres and Jaffes (2014) are quite clear that they are using Shannon's definition of entropy, H, to quantify, for example, language structures. Jaffes and Febres (2015) use decrease in Shannon entropy to identify synergy. When P(N) = H(non-synergistic)/H(synergistic), is greater than one, a synergistic relationship exists.

Using this definition, Jaffes and Febres (2015) show synergistic processes not only decrease Shannon entropy but increase "work output". But in the paper, "work" does not refer to the physics definition, but rather is a "work parameter" or an efficiency parameter used to measure the effectiveness or productivity of the output of the system. This for an economy this can be GDP as in the Haussman et al. reference. But this is not always the case. GDP goes up when existing house prices rise, but the economy has not increased productivity. By the way, in my language, synergism increases the order of the system, corresponding to a lower Shannon entropy.

On page 3 I cannot tell how the author identifies synergy. Probably the concept is the same as Jaffes and Febres (2015). But without setting the discussion within the framework of Jaffes and Febres I have to guess.

The categories of open systems.

Dissipation in the natural sciences is where stored energy or mechanical energy is turned into heat. The definition on page 3 by using energy rather than heat means something different. It is unclear what G and S are and how they are to be measured. The context would suggest G is the Gibbs' free energy and S is the thermodynamic entropy. But later the free energy is taken as a proxy for work output, and S probably means the Shannon entropy.
Aggregation. It must be clear how to evaluate S and G for to see the effect of aggregation. What does it mean for the stock market?

Equilibration (with the environment) reduces S, as heat passes to the environment and the free energy is utilised.

Synergising. The cannon ball example does not help me. Implicit is the idea that energy can be captured to do work.

When a dilute mix of hydrogen and oxygen is compressed, the hydrogen interacts with oxygen to produce water. The free energy has become available because the particles can interact. Better to talk in terms of Jaffes and Febre (2015)

The main text

Table 1 is unhelpful, as I cannot see how Delta G and Delta S can be quantified. I have no idea what these are in the particular cases mentioned. Dissipation in reference to war would normally mean the heat produced in the conflict. But here it means something and again, probably something different for the stock market.

Table 2, claims to provide quantitative data for synergistic processes. Firstly, the output of each system is taken to be a proxy for free energy. As mentioned in the introduction, this is not generally the case. In the case of ants, as the output parameter is the energy consumption, it can be related to free energy flow into the system (that sustains the system away from equilibrium), but it does not necessarily apply to other examples.

Secondly, most of this table comes from Febre and Jaffes (2015) where the Shannon entropy is used as the entropy, and the synergy is identified by the decrease in the Shannon entropy, not the thermodynamic entropy S. This allows Febre and Jaffes (2015) to argue that an increase in negentropy (related to a reduction in Shannon entropy) correlates with a increase in the efficiency of the work output of the system. Fair enough.

The conclusion section

The first sentence in the conclusion of the current paper is wrong. The second law does not imply that the total energy is the sum of free energy and entropy. It is the entropy in bits, multiplied by Kbln2T, plus the free energy that is conserved in an isolated system. But it is even worse to claim that the data shows the “total energy is the sum of free energy and entropy” for an open system. I am not convinced the data shows any such thing.

In summary, definitions of the terms need to be made clear based on Febre and Jaffes. But even then, the argument presented is likely to fail. Free energy is not always, and may seldom be, related to the intuitively chosen “work output” parameter, each case must be treated separately.