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Earth System Dynamics Discussions

Interactive comment on "No way out? The double-bind in seeking global prosperity along with mitigated climate change" *by* T. J. Garrett

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Thank you for your comment.

The prognostic model relating GDP to atmospheric CO2 concentrations is based on the diagnostic equations 10 and 15 and the prognostic equations 29 to 31. The full description is in Section 4 of the article. I wrote the code in matlab, but there is nothing special about matlab for this purpose. Any other tool could be used.

I think Figure 4 contains something like the stock and flow diagram you are seeking, however perhaps in a slightly different sense than what is most familiar.

My feeling is that some care must be taken when making a discrimination between stocks and flows. Stocks cannot form or be sustained without flows. The second law

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requires that all stocks of internal energy must dissipate into a lower potential form over time. Thus, sustaining or growing a stock must require a net convergence of energy from a higher potential.

For example, our body mass might be considered a stock. But in another sense it might be considered a flow because the existence of our mass entails a consumption of high potential food energy while we dissipate low potential heat energy. When the flow in and out of the system is in balance, then our body mass is in equilibrium, but without food consumption our bodies necessarily decay. Thus, the second law demands that the stock and the flow be inseparable. No stock exists without a flow, except at absolute zero (which doesn't exist).

Also, it is only by eating more than we dissipate that we can gain weight. Is our weight gain a "flow"? Perhaps it can be seen this way because it has units of mass over time. But I think the more accurate way of viewing this is that the weight gain represents an increase in a flow rate. At equilibrium, heavier people eat more and emit more heat.

An identical approach is taken here with respect to civilization as a whole. Civilization wealth might be considered a stock in much the same way that body mass is considered a stock. But also in the same way, civilization wealth is tied through the constant λ to a flow, which is the rate of consumption of energy. As shown in Figure 1, civilization is linked through an interface to primary energy reservoirs, entailing a flow of energy down a "staircase" in potential energy. As civilization goes through its machinations, civilization dissipates the energy it consumes further down the staircase, losing the energy as heat to the environment.

In the model described here, a large, wealthy civilization consumes more energy than a small one because it has a larger interface with respect to primary energy reservoirs, and also with respect to the environment. How does civilization grow to this size when civilization always loses heat to the environment? As with a person's body mass, it must be due to a convergence of energy along the potential surface where civilization lies.

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Here it is supposed that this convergence generating civilization wealth is quantified fiscally through the global GDP. Again, is the GDP a flow (as argued by reviewer 3)? Sort of, because it has units of currency over time. But it is not a flow in the same sense that consumption is a flow. Rather the GDP represents thermodynamic work done to expand the size of civilization and thus the rate of flow.

The key thing here comes from looking at figure 1. GDP is associated with an interface expansion that lies along a constant potential surface (or "step") that is at right angles (mathematically, it is "orthogonal") to the rate of flow down the potential "staircase". Just as our weight gain is not the consumption of energy supplies, which exists whether or not we gain weight, GDP is not necessarily tied to the energy consumption rate. Rather, it is a quantity that is orthogonal to the down-staircase flows, and instead represents an extension of the capacity of civilization to facilitate these flows.

In a model where GDP is orthogonal to energy consumption, consumption should not be subtracted from GDP to obtain an "investment", as argued by Reviewer 3, even if this is what is normally done in economic growth models. Quantities that are orthogonal can never be added or subtracted. Purely from a mathematical perspective, this is nonsense, like subtracting the x co-ordinate from the y co-ordinate on a cartesian plane. Inflation-adjusted GDP simply represents the rate of change in the rate of consumption and dissipation of energy.

Note that all of the above rests on the falsifiable hypothethesis that λ is a constant, which I take as true based on observational validation. λ links the thermodynamics shown in Figure 1 to the flow diagrams for the global economy shown in Figure 4. I hope these diagrams are sufficiently clear.

Interactive comment on Earth Syst. Dynam. Discuss., 2, 315, 2011.

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