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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 C. Herrmann-Pillath

Prof. Herrmann-Pillath's constructive review of this paper and prior papers have contributed greatly to their improvement. The effort is much appreciated. Some specific comments are addressed below.

This approach has the great advantage that it does not need to disaggregate the economic system, which is normally done by IAM models. These models have to introduce certain assumptions about economic variables which are highly problematic, therefore rendering predictions almost arbitrary, as has been stated

clearly in a recent assessment by a leading economist working in this field (see Pyndick 2013). Therefore, Garrett's approach is highly welcome.

Thank you for the positive comments and in particular for the reference to Pindyck (2013) which is now added to the introduction.

In my earlier review, I already questioned the definition of wealth. It comes close to the economic notion of 'capital', but uses gross values of production that do not include depreciation. However, depreciation is introduced in section 2.4 as a 'decay parameter'. I think that this should be considered also in the definition of wealth, in order to be exact in the economics. In other words, I think that Garrett now includes physical decay, but not economic depreciation (in other contributions, this is related to inflation, which I think is bad economics). So, I have the impression that the two parts are not consistent, because including decay was one of the improvements that I noticed in the new model.

In my view, one of the rather elegant results that comes from λ being a constant is that physical decay is equivalent to either economic depreciation *or* inflation. The difference between the nominal and inflation-adjusted GDP, or the GDP deflator, is implicitly a representation of physical decay. The way to think about it, I think, is that wealth is purely an energetic representation of the capacity to enable reversible circulations at any given instant within the economic system. Economic production, the GDP, or the addition to wealth, is more explicitly tied to the material growth of the system. Civilization is made of matter not energy, so it's growth is material. Therefore, physical decay is best ascribed to production not wealth – it is the matter that is decaying. As is described in greater detail in Part I, it follows quite naturally from λ that the magnitude of the decay rate is related to the GDP deflator. If there is zero decay, all of the nominal GDP is the real GDP. Otherwise, some fraction is lost to inflation.

As for the measure of wealth, that would imply using NWP Net World Product in the original time series. Further, Garrett states that the physical manifestation of

wealth is networks, both technological and human. This perspective is essential for arguing that in measuring global production, it is not necessary to distinguish between investment and consumption, as we can conceive of consumption as producing and maintaining the human network. Obviously, this presupposes a fully-fledged materialist theory of human consumption activity (such as in the arts, fashion etc.) in relating all this to the energetics of the economy. I think that this is possible (see my own work, Herrmann- Pillath 2013). However, this also means that using the GWP as a measure may be problematic because the GDP data do not include the production of public goods by political entities funded by taxes. This is a well-known limitation of national accounts and certainly is highly relevant for Garrett's argument. For example, roads, airports, harbours or power stations as essential parts of the 'hardware' of the economy would be left out of Garrett's measure of wealth also pertinent for the analysis of innovation, which in New Growth Theories is treated as a positive externality (so, by definition is excluded from national accounts).

The argument that government funded infrastructure development is not tallied in the GDP is surprising to me. I help run a company that sells meteorological instrumentation. All sales thus far have been directly or indirectly funded by the governments of the United States or Switzerland. The company builds instruments through acquisition of parts and construction equipment from other companies, all labor payments are reported to the IRS by company employees, and company profits are themselves reported and taxed. I am quite sure that all these expenditures get included in GDP calculations, independent of the original funding source.

As an aside, one frustration of using GWP data is that the United Nations reports the global statistic to the *dime* (i.e. thirteen significant digits), while providing no estimate of the measurement uncertainty in the statistic. I agree that all measurements are problematic to some degree. However, it is critical to assess the extent. Unfortunately, this does not appear to be standard practice for this particular statistic.

Another technical problem is the use of market exchange rates for measuring GWP which Garrett simply imports with the data base that he uses. I think that only purchasing power parities make sense, given the focus on energetics. As is well known, market exchange rates distort the measurement of the true standard of living. Especially for less-developed countries. However, it is this 'real' level of economic activity that drives energy transformations. So, I think PPP conversions should be used.

PPP measures are focused on the standard of living of people. From a strictly energetic or physical standpoint, people seem a rather arbitrary choice. The energy consumption by human bodies is only about 4% of the global total. The issue of PPP versus MER currency was addressed in more detail in the Supporting Information section of Part I where it is stated that:

"It might be argued that MER valuations are misleading and that PPP dollars should be used instead (Cullenward et al., 2011). PPP dollars are adjusted from MER dollars on the premise that market exchange rates do not accurately reflect the price of equivalent baskets of goods in differing countries. In principle, the theory presumes that equivalent baskets should be worth the same after adjusting for the exchange rate, and that any disequilibria should be expected to diminish over time. Discrepancies between PPP and MER valuations have been used as a tool to assess whether currencies are overvalued. Criticisms of the approach have included the difficulty of establishing an equivalent basket of goods between disparate cultures, and the observation that disequilibria diminish rather slowly with a half life of three to five years, perhaps due to the competing effects of international and domestic markets on the pricing of goods (Rogoff, 1996).

The work here addresses different questions than those where PPP valuations would be relevant. It is not concerned with short-term inequalities or with nations. What is considered instead is only the sum of all human activities within the global economy, including all components, with an eye to variability in the long run. No specific resolution

is made of people or their baskets of goods, nor even of nations, nor of the economic evolution of parameters that have doubling times of anything less than decades.

Effectively, the economics described here considers only one "basket of goods", and that is civilization as a whole, including all its composite networks, both social and physical. Purchasing power parity calculations are not obviously applicable in this situation. And, in any case, if they were performed according to theoretical expectations, the disequilibria between nations would be theoretically expected to damp out more quickly than the timescales of interest in this study."

Accordingly the following text is now added

MER units are used rather than purchasing power parity units (PPP) since the focus is not on short-term inequalities between people and nations but rather the sum of all activities within the global economy with an eye to variability in the long run.

Considering my arguments an on necessary modifications of the fundamental quantities, the questions arises whether the empirical regularity of a fixed ratio between wealth and energy use would survive the statistical corrections. I have no preconceived opinion on this, but of course the challenge is that we cannot implement those corrections, especially we cannot measure the stock of public goods over longer time periods. Therefore I advise that Garrett should present some reasons why he regards his measure as a good approximation.

It is true that a different definition of wealth would be unlikely to have a fixed relationship to rates of energy consumption in the statistics. But the definition of wealth that is used is mathematically very precise, and is the one that is used. To give an analogous example, the energy of a photon has a fixed linear relationship to its frequency. One could make the argument that Planck got it wrong because the energy of an ocean wave doesn't have a fixed linear relationship to it's frequency: amplitude also factors in. But, that doesn't matter. Ocean waves aren't photons. The fundamental basis for quantum mechanics remains robust.

Garrett's work concurs with views such as articulated in Ayres and Warr (2009) that innovation is tantamount to improvements in energetic conversions, in his words, the rate of return. I agree with this view, but want to point out that this also means that an essential driver of economic growth remains unexplained, just as in the earlier neoclassical growth models that Garrett briefly sketches in the appendix. So, the question is whether this is also a weakness for a physical model advocated by Garrett. In his narrative, technological progress happens because of both technology and availability of reserves. Thus, one would guess that a standard economic model of resource extraction with technological change would be a proper complement. However, as has been shown by authors such as KÂÿmmel (2013), this approach would probably commit the mistake to assume that technology is a full substitute for energy. So, at this point a step towards further disaggregation of the physical model seems unavoidable.

I'm sorry. I'm not sure I understand. What is the essential driver of economic growth that is missed? Building from theoretical thermodynamic arguments, this paper identifies three forces for improvements in technological change at global scales: increased longevity, discovering energy reserves faster than they are depleted, and improved energy efficiency of raw material extraction. Technology and energy are not substitutes in any physically meaningful sense.

To sum up, Garrett's work is highly productive in opening up new ways of thinking about the human economy in the Earth System context. He tries to see the forest, whereas much modelling practice is busy with counting the trees.

References

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