Whereas I am no authority on all the many production functions in the literature, I believe this to be an original and different way of connecting energy to economic production measures (He uses the word "value" to be a predictor of GNP. His "value" is an embodied energy concept(donor value concept) and he needs to say so. He is using embodied energy measure of real wealth to predict the aggregate dollar measures of value. This is not so different from emergy papers.

It may be a help to the author to read what this reviewer thinks he is presenting based on my limited time to spend on the paper. Where I have difficulty, the author might improve the English explanation.

With methodology typical of mathematical physics, for energy, labor, and capital he defines sets of coefficients (the word coefficient in some methodologies implies constants but not here). After expressions are combined in new ways these coefficients emerge as useful variables. He tweaks the units to make coefficients non-dimensional.

One set of coefficients represents the growth of energy use and labor use per unit increase in capital storage (which he calls investments). This seems strange on page 4, but he gives his rationale for it later in concluding page 11. (perhaps this should be moved up to the front?) The capital attracts the direct energy and the energy basis for labor (implied embodied energy of labor). The energy input is only that used by production sectors (coefficient s). Energy that goes directly to human consumer sectors is not included. In the first paragraph of page 5 please show the reader the missing step in equations from sE to wE (growth coefficient w).

Another set of coefficients represents the effect of each input (energy, labor, and capital) on productive output (which he calls value) when the others are constant. If I understand, on the lower half of page 5, he uses a single coefficient (not a hyperbolic curvilinear function) for marginal productivity (change in production output per unit change in input). This seems unrealistic if these remain as constants. But perhaps his manipulations create a curvilinear relationship for these coefficients that is embedded in his final equations???--perhaps he should clarify.

To handle technology and information, he uses a coefficient tau the time to make a technology jump. It is placed as a denominator in the equation for the coefficient of labor thus making a rate of labor reduction due to technological innovation. Isn't this tantamount to saying technology does not require energy--which would be contrary to the recent trends with power increases due to computer revolution? Maybe that is why his energy curve is

Review

off in the 1990's in Figure 1. Perhaps he might discuss this. What about information depreciation? The author explained that he didn't want to add information-technology as a 4th production input, but perhaps in the next paper he should.

In most places he uses the word "energy" when he should use available energy(exergy). He might make it clear that one is the approximation for the other. His book has more explanation. He should clarify if he is using fossil fuel equivalents. If the energy is in coal equivalents and doesn't attempt to include environmental energies, then there is less error in not multiplying by transformities to get available energy in units of one kind(emergy).

The depreciation coefficient u is held mostly constant at 0.05. Depreciation is a function of scale through many orders of magnitude. 5%/yr is OK for smaller things of the economy; highways and infrastructure are more like 2% and shared information is 1% or less.

In the second paragraph of page 8, the author is using the maximum power principle, but may not realize it. He should mention the similarity. Another set of coefficients is introduced for percent growth(exponential growth) and worked into other calculations by setting the strategy ofself organization so as to maximizing outputs and minimize inputs?

Fix the English in footnote 2.

In my approach to production functions and macroeconomics (chapter 23 in my Ecological and General Systems book (Systems Ecology in its first edition), systems diagrams of production were drawn first and then equations derived. I wish the author would show a system diagram of the production function, its inputs, and the money counter currents. I realize that the physics discipline often derives relationships piecemeal without a systems diagram, letting larger scale relationshps emerge bycombining math (Feynman being an exception).

I think this is a splendid contribution. Some extensive clarifications to help general readers like me could be made as implied above. On the other hand journal policy may expect equations to tell the story without much explanation.

Reviewe

This paper evaluates slightly modified traditional multiplicative production functions to better consider the direct and indirect use of energy in economic production. It is a relatively short (21 pages plus 3 figures) presentation of the essence of the author's recent book: Pokrovski, V.N. 1999. Physical Principles in the Theory of Economic Growth. Ashgate Publ. Company, Brookfield, Vermont, 162 pp.

Whereas I found his book complex and difficult, this paper is much clearer. I recommend this paper be published in ENERGY. It will also help make his book more accessible, but, this paper ought to cite his own book in its references, and make some statement explaining how this paper is a summary, abridgment, or extension of the book.

The paper uses the effect of energy consumption as a way to understand the embodiment of energy in economic products evaluation, including that in production of capital assets including technology, and that going to consumers, and giving energy embodiment to human labor.

Part of the global confusion on the role of energy in technological growth is caused when people think information and technology is human genius substituting for energy. Actually, it is the energy that sustains the necessary information and technology. This paper deals with the issue nicely by developing coefficients of energy effect on the necessary capital and technologically educated labor. His yield of product value is embodied energy which is necessary for labor and capital inputs to the production, along with the direct input of energy. He calculates coefficients of marginal productivity, which may be important for relating energy limits for purposes in the future

After including his production function in equations of a model for national growth, he uses energy consumption data to simulate growth, with a good match to observed growth of the US economy. He shows that the growth of value correlates with the growth of electricity, as one of the mechanisms of coupling of primary production to value in capital and labor.

Reviewer 1

There should be a paragraph explaining that he adds money (gross domestic product circulation) in proportion to the production value, with a reasonable assumption that central banks adjust money supplies to keep economy functional, and this turns out to be tantamount to keeping a constant ratio of dollars to energy based production of value. Pokrovski's book has long (and not too clear) sections that deal with market values and prices related to production value. This paper for Energy only needs a short section explaining how his calculated graphs of the future express production values in constant dollars.

The author needs to clarify his use of the words "substitution" and "complement" of energy, capital, labor, etc. (Readers will confuse the two ways that production factors substitute for each other.) I believe he means substitution in the important sense of embodied energy equivalents, not in the simple traditional sense of increasing one factor so as to counteract the weakness of another factor. Any production factor can be regarded as a substitute in the mathematical sense of allowing another factor to be less. Traditionally, this has been dealt with by Isoquant graphs. I tried to clarify these two different meanings of "substitution" on page 261 of my book, <u>Environmental Accounting</u> (Wiley, 1996). This paper does a great job in showing the way energy is inherent in technological civilization.

I believe the paper is original and relevant and meets the requirements of the ENERGY checklist and is acceptable after minor revision (adding a couple of clarification paragraphs as mentioned above).