MACROSCALE MODELING LINKING ENERGY AND DEBT: A MISSING LINKAGE

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Overview

Monetary models of finance and debt often assume that energy resources and technology are not constraints on the economy. Energy transition scenario models often assume that economic growth, finance and debt will not be constraints on the energy transition. These assumptions must be eliminated, and the modeling concepts must be integrated if we are to properly understand the dynamic interactions between energy and financial sectors of the economy as well as the dynamics of a low-carbon and/or renewable energy transition over multiple decades.

Methods

Here the research seeks to integrate macro-scale system dynamics models of money, debt, and employment (specifically the Goodwin and Minsky models of (Keen, 1995, Keen, 2013)) with system dynamics models of biophysical quantities (specifically population and natural resources such as in (Meadows et al., 1972, Meadows et al., 1974, Motesharrei et al., 2014)). Table 1 outlines the equations for both models.

Table 1. Equations for the biophysical and monetary models to be linked in this research.

Equations for Biophysical model (Motesharrei, 2014)	**Equations for Economic model** (Keen, 1995)	
▪ $\frac{d}{dt}X_c = \beta_c X_c - \alpha_c X_c$;(Commoner population) ▪ $\frac{d}{dt}X_e = \beta_e X_e - \alpha_e X_c$: ;(Elite population) ▪ $\frac{d}{dt}y = \gamma y(\lambda - y) - \delta X_c y$;(Nature) ▪ $\frac{d}{dt}w = \delta X_c y - C_c - C_e$;(Wealth) ▪ $C_c = \min\left(1, \frac{w}{w_{th}}\right) s X_c$;(Commoner Consumption) ▪ $C_e = \min\left(1, \frac{w}{w_{th}}\right) \kappa s X_c$;(Elite Consumption) ▪ $\alpha_c = \alpha_m + \max(0, 1 - \frac{C_c}{sX_c})(\alpha_M - \alpha_m)$;(Commoner Death Rate) ▪ $\alpha_e = \alpha_m + \max\left(0, 1 - \frac{C_e}{sX_e}\right)(\alpha_M - \alpha_m)$;(Elite Death Rate)	▪ $a = a_0 \times e^{\alpha t}$;(Labor Productivity) ▪ $N = N_0 \times e^{\beta t}$;(Population) ▪ $Y = a \times L$ (Real Output) ▪ $K = v \times Y$ (Capital) ▪ $\lambda = \frac{L}{N}$;(Employment Rate) ▪ $\frac{dw}{dt} = w[\lambda] \times w$;(Real Wage) ▪ $I = \frac{dK}{dt} = k\left[\frac{\Pi}{K}\right] Y - \gamma \times K$;(Investment) ▪ $\left[\frac{\Pi}{K}\right] = \frac{\Pi}{v \times Y} = \frac{\pi}{v}$;(Capital Investment Function)	▪ $\pi = 1 - \omega - b$;(Profit share) ▪ $\omega = \frac{W}{Y} = \frac{w \times L}{L \times a} = \frac{w}{a}$;(Wage Share) ▪ $b = \frac{B}{Y} = \frac{r \times D}{Y}$;(Banker's share) ▪ $\frac{dD}{dt} = r \times D + I - \prod$;(Debt) ▪ $r = \zeta + \frac{D}{Y}$;(Rate of Interest)

Results

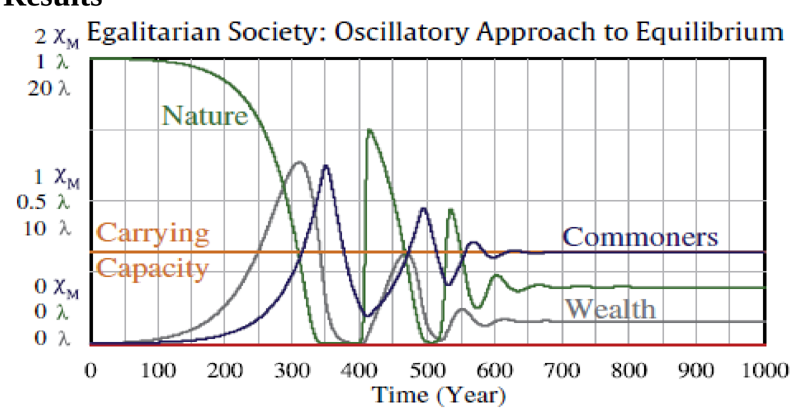

Figure 1. A typical (long-term) result of oscillating population and wealth that converges over time to an equilibrium.

There are not yet results for integrating the two models. Thus, we show typical results from each simulated independently. Figure 1 shows an example from (Motesharrei, 2014), the biophysical model, in which over the long –term population cycle the number of "commoners" converges to the carrying capacity based upon the maximum resource base (λ) and production per capita (δ). Figure 2 as debt is accumulated over time an increase in inflation and decrease in employment is observed, inferring to a recession in the future.

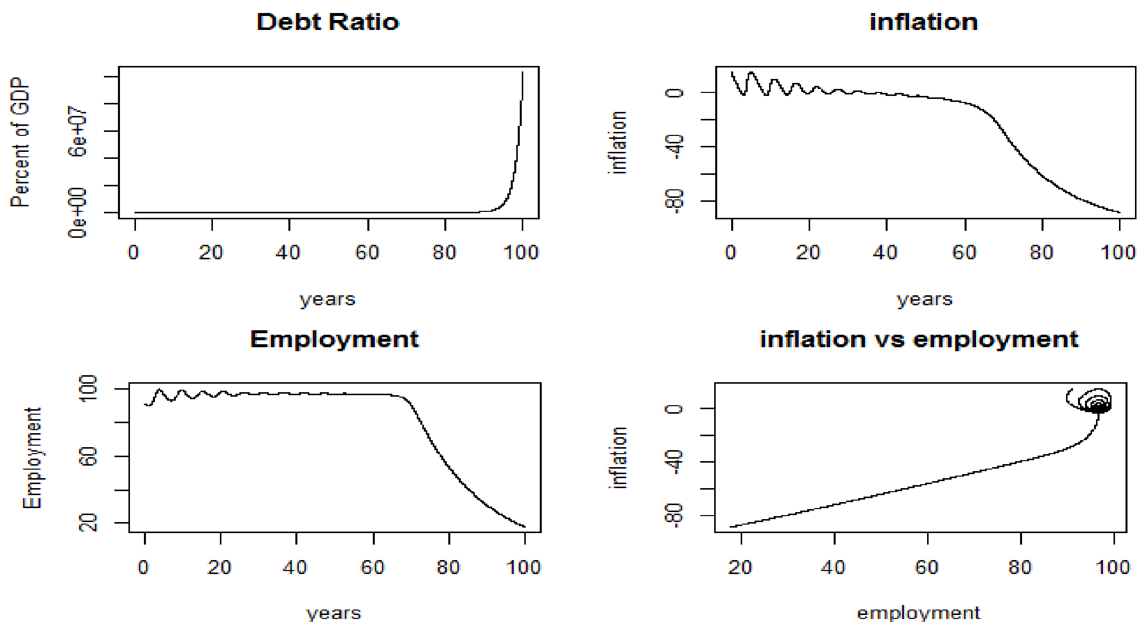

Figure 2. Results from Keen's economic model (Keen, 2013), with rate of interest on loans adjusted to 5%, which show a financial collapse is possible to occur after a period of stability.

Conclusions

This type of modeling is anticipated to help answer important questions for a low-carbon transition (two examples):

1. How does the rate of investment in "energy" feedback to growth of population, economic output, and debt?

The more we invest in "energy" sectors, the more capital, labor, and natural resources will be mobilized to become part of those sectors. The larger this mobilization, the higher the cost of energy will become as there is an increasing number of "energy" sector worker's dependent upon selling energy to a decreasing set of "non-energy" sector consumers. Increasing labor and capital shares for energy is the exact opposite trend of industrialization as we know it, and there is a critical need to understand the associated feedbacks.

2. How does the capital structure (e.g., fixed costs versus variable costs) of fossil and renewable energy systems relate to and affect economic outcomes?

Renewable and low-carbon energy systems (e.g., PV, wind, nuclear, electrochemical storage) are characterized by a much higher fraction of fixed (capital) costs as compared to fossil energy systems (e.g., coal, natural gas, and oil). Higher fixed costs systems are more favorable in certain (e.g., predictable) and lower growth (with low discount rate) environments whereas lower fixed cost systems are more favorable in uncertain and high growth situations (Chen, 2016). Low economic growth, associated with low discount rates, also make high fixed cost and longer-life assets, like renewable systems, more favorable. Thus, we should expect low growth ("secular stagnation") to be associated with low interest rates and high renewable energy installations, just as has happened over the last several years. We anticipate this modeling framework to inform the relative economic viability of fossil versus renewable technologies in periods of growing (historical U.S.), stagnant (current U.S.), and declining energy demand.

References

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