System Dynamics must Supplant Equilibrium Modelling in Economics

Preprint

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SYSTEM DYNAMICS MUST SUPPLANT EQUILIBRIUM MODELLING IN ECONOMICS

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ABSTRACT

The development of macroeconomics has been driven by the laudable aim of giving it sound foundations. But economists have erred by presuming this must mean deriving macroeconomics from microeconomics. I show that macroeconomics can be derived directly from macroeconomic definitions, resulting in a simple complex model consistent with Hyman Minsky's Financial Instability Hypothesis and akin to Lorenz's foundational model in fluid dynamics. Economics must also be made consistent with Thermodynamics, in the first instance by acknowledging the role of energy in production, which current economic models do not. The failure of economics to acknowledge the Laws of Thermodynamics is writ large in the appallingly bad empirical assumptions used by Nordhaus to trivialize the dangers of climate change.

Keywords: Macroeconomics, System Dynamics, Climate Change

NOMENCLATURE

L	Employment
N	Population
β	Rate of population growth
λ	Employment Rate
λ_S	Slope of linear wage change function
λ_Z	Zero intercept of wage change function
w	Wage rate per worker
w_Δ	Wage change function $= \lambda_S \times (\lambda - \lambda_Z)$
W	Wages
Y	GDP (total output)
ω	Wages Share of GDP
K	Capital Stock
v	Capital to GDP ratio
Π	Profit
π_s	Profit to GDP ratio
π_r	Profit to Capital ratio (profit rate)
π_S	Slope of linear investment function
π_Z	Investment = Profit in investment function
I_G	Gross investment
i_G	Investment function $= \pi_S \times (\pi_r - \pi_Z)$
δ_K	Depreciation rate
g_r	Growth rate $= \frac{i_G}{v} - \delta_K$
D	Private debt
r	Rate of interest
d_r	Debt to GDP ratio
a	Output to Labor ratio
α	Rate of change of the output to labor ratio

1. INTRODUCTION

As then-President of the American Economic Association Robert Lucas put it in 2003, "Nobody was satisfied with IS-LM as the end of macroeconomic theorizing. The idea was we were going to tie it together with microeconomics and that was the job of our generation" [1, p. 20]. This ambition was always ill-founded, since, as Physics Nobel Laureate Philip Anderson put it, "More is Different" [2]. This point was accidentally confirmed by microeconomists themselves, when Sonnenschein and others proved that a downward-sloping market demand curve could not be derived from the aggregation of individual demand curves that themselves were downward sloping [3]. However, the so-called Sonnenschein-Mantel-Debreu theorem was ignored in the development of Real Business Cycle and then Dynamic Stochastic General Equilibrium models, which famously predicted rosy economic prospects immediately before the 2007 Global Financial Crisis [4]. But even after this failure, Neoclassical economists continue to believe that macroeconomics should be derived from microeconomics: "Starting from explicit microfoundations is clearly essential; where else to start from?" [5, p. 47].

In fact, Richard Goodwin's neglected macroeconomic growth cycle model [6] and an extension compatible with Hyman Minsky's Financial Instability Hypothesis [7] can be derived by differentiating incontrovertibly true macroeconomic definitions with respect to time, and then using the simplest possible behavioral assumptions to link the system states. The result is a stylized macroeconomic model with comparable status in economics to Lorenz's celebrated model of turbulence in fluid dynamics [8].

2. MATERIALS AND METHODS

Differentiating the definitions for the employment rate $\lambda \equiv L/N$, wages share of GDP $\omega \equiv W/Y$ and private debt ratio $d_r \equiv D/Y$ with respect to time yields the following three dynamic renditions of these definitions (where $\hat{x}$ is used to signify $\frac{1}{x}\frac{dx}{dt}$):

$$\hat{\lambda} \equiv \hat{Y} - \left(\hat{a} + \hat{N}\right) \quad (1)$$

$$\hat{\omega} \equiv \hat{W} - \hat{Y} \quad (2)$$

$$\widehat{d_r} \equiv \hat{D} - \hat{Y} \quad (3)$$

These definitions are turned into a model using the assumptions listed under Nomenclature ($\hat{a} = \alpha, \hat{N} = \beta, Y = K/v\,, dK/dt = I_G - \delta_K \times K, i_G = I_G/Y = \pi_S \times (\pi_r - \pi_Z)$):

$$\frac{d}{dt}\lambda = \lambda \times \left(g_r - (\alpha + \beta)\right) \quad (4)$$

$$\frac{d}{dt}\omega = \omega \times (w_\Delta - \alpha) \quad (5)$$

$$\frac{d}{dt}d_r = i_G - \pi_s - d_r \times g_r \quad (6)$$

2.1 Subtitle

Subtitles should be bold but not all-capped.

3. RESULTS AND DISCUSSION

Minus its financial component (the 3rd equation and the inclusion of interest payments on debt as a deduction from profits) this model is identical to Goodwin's growth cycle model [6]. It has a neutral equilibrium and generates closed cycles in employment and income distribution for any non-equilibrium starting point that capture the cyclical characteristics of OECD economies in a satisfactory manner [9]. With its financial component, the model has two meaningful equilibria, one with finite employment rate, wages share and debt ratio values and another with zero employment rate and wages share with a infinite debt ratio that Grasselli and Costa-Lima characterized respectively as the "good" and "bad" equilibrium[10]. For realistic parameter values, the "good" equilibrium is unstable and acts as a strange attractor of the Pomeau-Manneville class [11]: the model appears to converge towards the good equilibrium with declining cycles in the growth rate, employment and income distribution, only to diverge from this towards the bad equilibrium—see Figure 1.

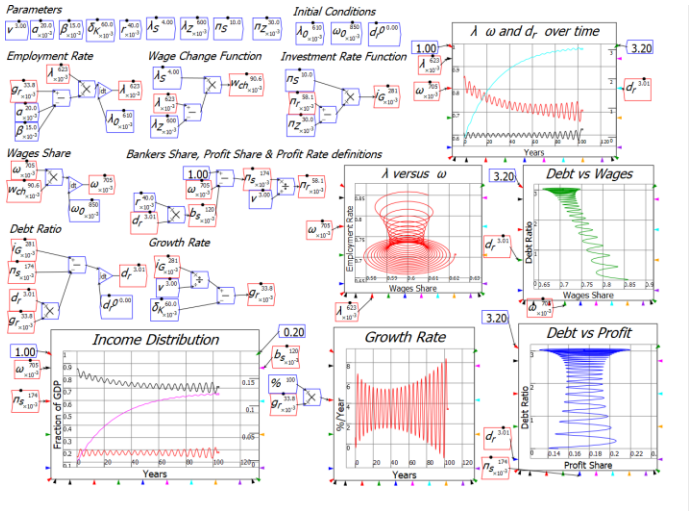

FIGURE 1: Simulation of this model in the Open Source system dynamics program Minsky—see https://sourceforge.net/projects/minsky/.

Though the model is as stylized a model of the macroeconomy as Lorenz's was of fluid dynamics, its dynamics mirror the recent behavior of the US economy, including a period of diminishing cycles before an eventual crisis, a rising ratio of private debt to GDP, and increasing inequality as the wages share of GDP declined while the share going to the FIRE sector (Finance, Insurance and Real Estate) rose—see Figure 2.Crucially, it provides an endogenous explanation for the 2007 Global Financial Crisis, an explanation of which has eluded mainstream economists—apart from blaming it on unspecified "exogenous shocks" [12].

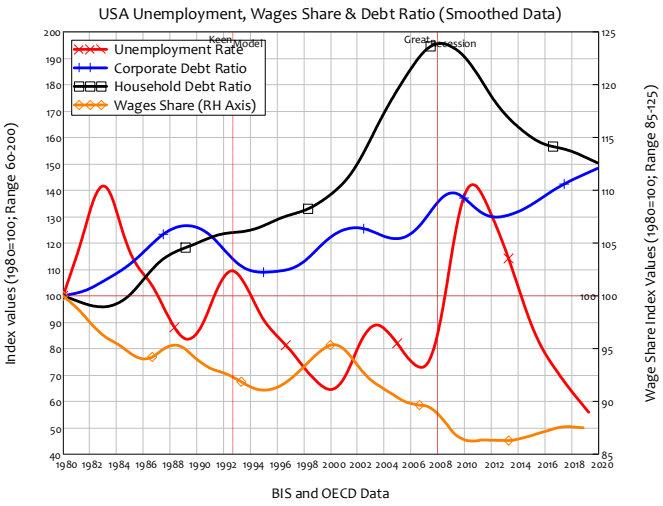

FIGURE 2: The recent behavior of unemployment, income distribution and debt in the US economy

The model is a foundation from which other issues such as speculative borrowing, household debt [13], inventory dynamics [14] and climate change [15] can be considered. Extensions to include price dynamics, multi-sectoral production and the role of energy in production [16]can all be added in a similar fashion to its own development from definitionally true foundations. It

leads directly to a complex systems and system dynamics approach to economics, which I have developed the Open Source program *Minsky* to facilitate. Feedback from users with backgrounds in engineering, complex systems and ecology is most welcome.

Climate change, which is fundamentally driven by the human system of production and distribution, adds a new urgency to developing an ecologically sound, non-equilibrium approach to economics to replace the ecologically ignorant, equilibrium-fixated school of Neoclassical economics. The award of the falsely named "Nobel Prize in Economics"—it is actually the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel—to William Nordhaus in 2018 "for integrating climate change into long-run macroeconomic analysis" may give the impression that Neoclassical economists have seriously grappled with climate change. Nothing could be further from the truth.

In fact, Nordhaus trivialized the dangers of climate change in order to fit the topic into both the equilibrium constraints of Neoclassical modelling techniques, and his own prior belief that climate change could not be threatening to the economy.

He *simply assumed* that 89% of the US economy would be unaffected by climate change—all manufacturing and mining (26% of GDP), all non-water-based transportation (5.5%), all finance, insurance and non-coastal real estate (11.4%), all retail and wholesale trade (27.9%), all government services (14%), and even imports (2.1%)—because it happens in "carefully controlled environments that will not be directly affected by climate change" [17, p. 930].

He, in conjunction with other Neoclassical economists who purport to be experts on climate change [18, 19], assumed that the weak, nonlinear relationship between temperature today and GDP today could be used as a proxy for the impact of increasing the biosphere's average temperature through increased CO_2 due to climate change.

These absurd assumptions should have resulted in his research being rejected, rather than given the accolade of a "Nobel" Prize. But because referees for mainstream economic journals accept Milton Friedman's unsound methodological dictum that "a theory cannot be tested by the "realism" of its "assumptions"" [20, p. 23], Nordhaus's approach came to dominate the economic analysis of climate change. This has affected the IPCC Reports, which are drafted by economists whose views are consonant with Nordhaus's as FAQ 10.3 in the IPCC 2014 Report indicates:

FAQ 10.3 | Are other economic sectors vulnerable to climate change too? Economic activities such as agriculture, forestry, fisheries, and mining are exposed to the weather and thus vulnerable to climate change. Other economic activities, such as manufacturing and services, largely take place in controlled environments and are not really exposed to climate change. [21, p. 688]

Climate change is such a crucial topic, and the work of Neoclassical economists on it has been so bad, that this alone is a reason to endeavor to replace this dated approach to economics with system dynamics.

4. CONCLUSION

Economics has remained immune to criticisms of its logical failings [22-24] and resistant to modern techniques of analysis for the past century. While as Blatt put it, its focus on equilibrium analysis could be justified in its foundational years in the 19th century, there is no justification for that now:

A baby is expected to first crawl, then walk, before running. But what if a grown-up man is still crawling? At present, the state of our dynamic economics is more akin to a crawl than to a walk, to say nothing of a run. Indeed, some may think that capitalism as a social system may disappear before its dynamics are understood by economists. [25, p. 5]

Since Neoclassical economists show no proclivity to walk the walk of dynamics, practitioners from other fields such as system dynamics and thermodynamics should feel no shame in invading their territory and walking that walk for them.

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