Energy and chaos: Modelling Energy in a dynamical growth model with chaotic bifurcation

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Overview

While most of the macro-economic literature focuses on (general equilibrium) stationary behaviors, only a few papers try to model economic growth as a truly dynamical system exhibiting cyclical and chaotic patterns. Building on Goodwin (1967), Keen (2011) achieves this purpose by proposing a system of 3 non-linear differential equations in an economy with capital and labor, which exhibits a cyclical behavior in the neighborhood of an equilibrium, while, outside this neighborhood, the system follows a transition towards chaos in the sense of Pomeau and Manneville (1980). Such dynamics have been introduced in physics for the study of hydrodynamical turbulences. Their emergence in this economic environment can be interpreted as an account of Minsky's (1977) market instability concept. The key variable of the economy becomes indeed the ratio private-debt/output. The possible unbounded increase of this ratio is responsible for the appearance of chaos.

In the present paper, I study several extensions of Keen's initial system.

Methods

The first one obtains by:

- Adding energy as an input in the production sector;

-Rewriting the production sector in the Putty-Clay flavour. More precisely, taking inspiration from Atkeson and Kehoe (1994), we assume that the ex ante production function is of the CES type (Constant Elasticity of Substitution) while the ex post production function is Leontieff. Each capital vintage is characterized by its energy and labor efficiency. Given the price of energy and wages, machines and infrastructures whose marginal cost exceeds its profit are left idle. A random productivity shock enables to keep a smooth dynamical system despite the discontintuity introduced by the potential under-utilization of capital.

In a second extension, I introduce a public sector by means of public expenditures and taxes.

In a third extension, I rewrite the whole dynamical system in monetary terms ---so far, everything had been written in "real" terms (with relative prices, etc.), including in Keen (2011). For this purpose, I borrow from Keen (2010) the modelling of endogenous money circulating between bank accounts. A key assumption on the velocity of money enables to connect the monetary dynamics with the "real" one ---so that, we end up with an 8-dimensional dynamical system. This time, households, private firms and the public sector are all able to accumulate debt, and it is the subtle interaction of these various debt dynamics that may be responsible for the appearance of a chaotic behavior.
Numerical simulations show the asymptotic properties of these dynamics at work.

Results

I show, in the first extension, that the Putty-Clay structure of energy and capital has two consequences on the dynamics: first, the dynamics becomes stochastic and path-dependent (the history of investments matters at every point of time, and in a way that depends upon the realization of the random productivity shock), and consequently, the system admits no stationary point any more. Second, when the viscosity of capital (captured through the slowness of capital depreciation) is high enough, the transition to chaotic turbulence disappears. In other words, it is the speed at which capital becomes obsolete (in particular with regard to its energy efficiency) that is responsible for the appearance of a chaotic behavior.

In the second extension, I show that the public sector enables to counterbalance the intrinsic instability of the underlying dynamical system: Whatever being the viscosity of capital, there exist countercyclical public policies that allow the dynamics to escape from turbulence.

The third extension enables to provide a monetary analysis of the link between the 2005 peak oil (at least in terms of conventional extraction methods) and the subprime crisis of 2007-2009: the lenient (third) oil shock that was experienced from 2000 to 2007 did not have the recessive impact of the shocks in the 70s' because of the easiness with which private actors and states could leverage. An easiness that has been favored by the huge leverage rates made possible by financial deregulation and the expansionary monetary policy of central banks. Debts were a substitute to cash in order to counterbalance the cost of oil. Around 2006, a “Minsky moment” occurred where most leveraged households started deleveraging because of the constraint on growth induced by the technical cap on oil daily extraction. The lack of growth made it indeed impossible to go further in the debt dynamics that has been favored by the oil shock. This opened the door for a (turbulent) debt-deflation effect that has been experienced in 2008.

Conclusions

As just mentioned, our model provides an analytical way to rethink about the links between energy and the financial crisis. Our dynamical approach also seems to be especially relevant for the economic analysis of an energy transition. It turns out, indeed, that banking credit is key for the financing of a transition towards alternative types of energy (say, from fossil energy to renewable ones). However, by making the dynamical system chaotically instable, too rapid an accumulation of debt may be a stumbling block on the route towards energy transition.

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