

A dynamical systems model for credit expansion, asset price bubbles and financial fragility

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Dynamic General Equilibrium views

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- Seeks to explain the aggregate economy using theories based on strong microeconomic foundations.
- Collective decisions of rational individuals over a range of variables for both present and future.
- All variables are **assumed** to be simultaneously in equilibrium.
- The only way the economy can be in disequilibrium at any point in time is through decisions based on wrong information.
- Money is neutral in its effect on real variables.
- Largely ignores uncertainty by simply subtracting risk premia from all risky returns and treat them as risk-free.

Voices of discontent

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- M. Morishima (1984): “If economists successfully devise a correct general equilibrium model (...) should it lack the institutional backing to realize an equilibrium solution, then [it] will amount to no more than a utopian state of affairs which bears no relation whatsoever to the real economy.”
- A. Kirman (1989): “[DSGE is] empty in the sense that one cannot expect it to house the elements of a scientific theory, one capable of producing empirically falsifiable propositions”.
- K. Arrow (1986): “In the aggregate, the hypothesis of rational behavior has in general no implications.”
- R. Solow (2006): “Maybe there is in human nature a deep-seated perverse pleasure in adopting and defending a wholly counterintuitive doctrine that leaves the uninitiated peasant wondering what planet he or she is on.”

Minsky's alternative interpretation of Keynes

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- Neoclassical economics is based on barter paradigm: money is convenient to eliminate the double coincidence of wants.
- In a modern economy, firms make complex portfolios decisions: which assets to hold and how to fund them.
- Financial institutions determine the way funds are available for ownership of capital and production.
- Uncertainty in valuation of cash flows (assets) and credit risk (liabilities) drive fluctuations in real demand and investment.
- Economy is fundamentally cyclical, with each state (boom, crisis, deflation, stagnation, expansion and recovery) containing the elements leading to the next in an identifiable manner.

Minsky's Financial Instability Hypothesis

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- Start when the economy is doing well but firms and banks are conservative.
- Most projects succeed - "Existing debt is easily validated: it pays to lever".
- Revised valuation of cash flows, exponential growth in credit, investment and asset prices.
- Highly liquid, low-yielding financial instruments are devalued, rise in corresponding interest rate.
- Beginning of "euphoric economy": increased debt to equity ratios, development of Ponzi financier.
- Viability of business activity is eventually compromised.
- Ponzi financiers have to sell assets, liquidity dries out, asset market is flooded.
- Euphoria becomes a panic.
- "Stability - or tranquility - in a world with a cyclical past and capitalist financial institutions is destabilizing".

Goodwin Model (1967) - Assumptions

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- Assume that

$$N(t) = N_0 e^{\beta t} \quad (\text{total labour force})$$

$$a(t) = a_0 e^{\alpha t} \quad (\text{productivity per worker})$$

$$Y(t) = \nu K(t) = a(t)L(t) \quad (\text{total yearly output})$$

where K is the total stock of capital and L is the employed population.

- Assume further that

$$\dot{w} = \Phi(\lambda)w \quad (\text{Phillips curve})$$

$$\dot{K} = (Y - wL) - \delta K \quad (\text{Say's Law})$$

Goodwin Model - Differential equations

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- Define

$$\omega = \frac{wL}{Y} = \frac{w}{a} \quad (\text{wage share})$$

$$\lambda = \frac{L}{N} = \frac{Y}{aN} \quad (\text{employment rate})$$

- It then follows that

$$\dot{\omega} = \omega(\Phi(\lambda) - \alpha) \quad (1)$$

$$\dot{\lambda} = \lambda \left(\frac{1 - \omega}{\nu} - \alpha - \beta - \delta \right) \quad (2)$$

Goodwin Model - Properties

- If we take Φ to be linear, (1) reduces to the Lotka-Volterra equations for the predator-prey model.
- To ensure $\lambda \in (0, 1)$ we take

$$\Phi(\lambda) = \frac{\phi_1}{(1 - \lambda)} - \phi_0$$

- Provided

$$\begin{aligned} \frac{1}{\nu} - \alpha - \beta - \delta &> 0 \\ \alpha + \phi_0 - \rho_1 &> 0 \end{aligned} \quad (3)$$

are satisfied, the trivial equilibrium $(0, 0)$ is a saddle point.

- Moreover the only other equilibrium

$$(\bar{\omega}, \bar{\lambda}) = \left(1 - \nu(\alpha + \beta + \delta), 1 - \sqrt{\frac{\phi_1}{\alpha + \phi_0}} \right) \quad (4)$$

is non-hyperbolic.

Example 1: Goodwin model

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Example 1 (continued): Goodwin model

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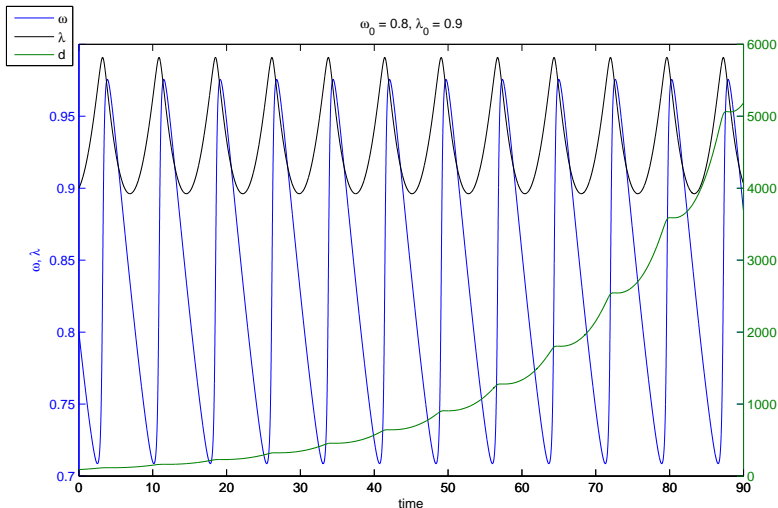
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Goodwin Model - Extensions, structural instability, and empirical tests

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- Desai 1972: Inflation leads to a stable equilibrium.
- Ploeg 1985: CES production function leads to stable equilibrium.
- Goodwin 1991: Pro-cyclical productivity growth leads to explosive oscillations.
- Solow 1990: US post-war data shows three sub-cycles with a “bare hint of a single large clockwise sweep” in the (ω, λ) plot.
- Harview 2000: Data from other OECD confirms the same qualitative features and shows unsatisfactory quantitative estimations.

Testing Goodwin on OECD countries

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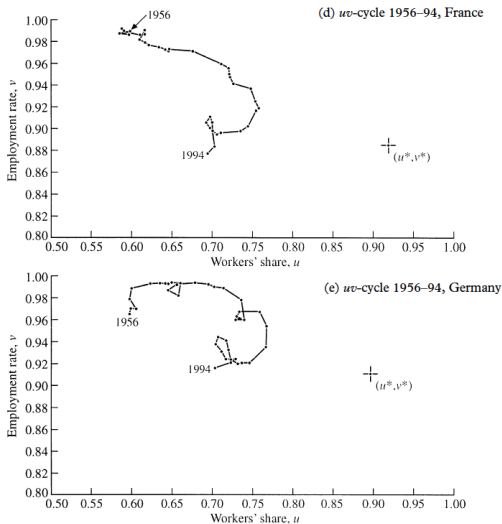


Figure: Source: Harvie (2000)

Introducing a financial sector (Keen 1995)

- Assume now that new investment is given by

$$\dot{K} = \kappa(1 - \omega - rd)Y - \delta K \quad (5)$$

where $\kappa(\cdot)$ is an increasing function the net profit share $\pi = 1 - \omega - rd$.

- This leads to external financing through debt evolving according to

$$\dot{D} = \kappa(1 - \omega - rd)Y - (1 - \omega - rd)Y$$

- We take

$$\kappa(x) = \kappa_0 + \kappa_1 e^{\kappa_2 x},$$

for constants

$$\kappa_0 < \nu(\alpha + \beta + \delta), \quad \kappa_1 > 0, \quad \kappa_2 > 0. \quad (6)$$

Keen model - Differential Equations

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Denote the debt ratio in the economy by $d = D/Y$, the model can now be described by the following system

$$\begin{aligned}\dot{\omega} &= \omega \left[\frac{\phi_1}{(1-\lambda)^2} - (\alpha + \phi_0) \right] \\ \dot{\lambda} &= \lambda \left[\frac{\kappa(1-\omega-rd)}{\nu} - \alpha - \beta - \delta \right] \\ \dot{d} &= d \left[r - \frac{\kappa(1-\omega-rd)}{\nu} + \delta \right] + \kappa(1-\omega-rd) - (1-\omega)\end{aligned}\tag{7}$$

Keen model - good equilibrium

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- If we define

$$\bar{\pi}_1 = \kappa^{-1}(\nu(\alpha + \beta + \delta)) = \frac{1}{\kappa_2} \log \left(\frac{\nu(\alpha + \beta + \delta) - \kappa_0}{\kappa_1} \right)$$

we see that one possible equilibrium for (7) is

$$\begin{aligned} \bar{\omega}_1 &= 1 - \bar{\pi}_1 - r \frac{\nu(\alpha + \beta + \delta) - \bar{\pi}_1}{\alpha + \beta} \\ \bar{\lambda}_1 &= 1 - \sqrt{\frac{\phi_1}{\alpha + \phi_0}} \\ \bar{d}_1 &= \frac{\nu(\alpha + \beta + \delta) - \bar{\pi}_1}{\alpha + \beta} \end{aligned} \tag{8}$$

Keen model - Irrelevant equilibria

- Other equilibrium points are given by

$$(\bar{\omega}_2, \bar{\lambda}_2, \bar{d}_2) = (0, 0, \bar{d}_2) \quad (9)$$

where \bar{d}_2 is any solution of the equation

$$d \left[r - \frac{\kappa(1 - rd)}{\nu} + \delta \right] + \kappa(1 - rd) - 1 = 0$$

- Another set of equilibrium points are

$$(\bar{\omega}_3, \bar{\lambda}_3, \bar{d}_3) = (0, \lambda, \bar{d}_1) \quad (10)$$

provided $1 - r\bar{d}_1 = \bar{\pi}_1$, that is

$$1 - r \frac{\nu(\alpha + \beta + \delta) - \kappa^{-1}(\nu(\alpha + \beta + \delta))}{\alpha + \beta} = \kappa^{-1}(\nu(\alpha + \beta + \delta))$$

Example 2 : convergent Keen model

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Example 2 (continued): convergent Keen model

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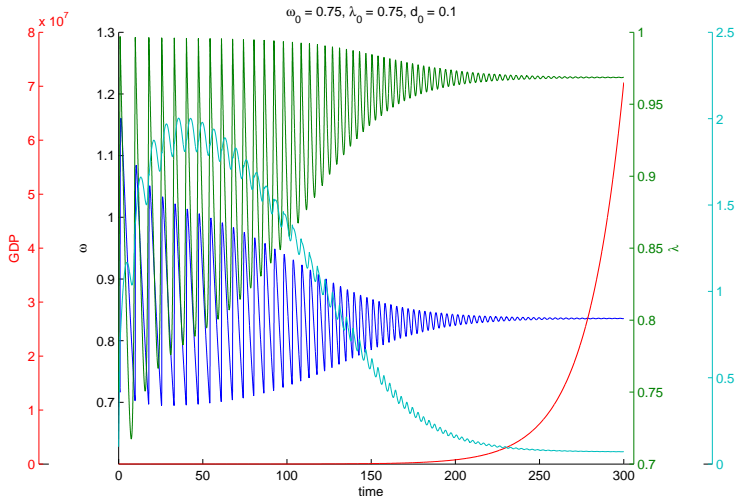
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Keen model - Explosive debt

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- If we rewrite the system with the change of variables $u = 1/d$, we obtain

$$\begin{aligned}\dot{\omega} &= \omega \left[\frac{\phi_1}{(1-\lambda)^2} - (\alpha + \phi_0) \right] \\ \dot{\lambda} &= \lambda \left[\frac{\kappa(1-\omega-r/u)}{\nu} - \alpha - \beta - \delta \right] \\ \dot{u} &= u \left[\frac{\kappa(1-\omega-r/u)}{\nu} - r - \delta \right] - u^2 [\kappa(1-\omega-r/u) - (1-\omega)]\end{aligned}\tag{11}$$

- We now see that $(0, 0, 0)$ is an equilibrium of (11) corresponding to the point

$$(\bar{\omega}_4, \bar{\lambda}_4, \bar{d}_4) = (0, 0, +\infty)\tag{12}$$

for the original system.

Example 3: divergent Keen model

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Example 3: divergent Keen model

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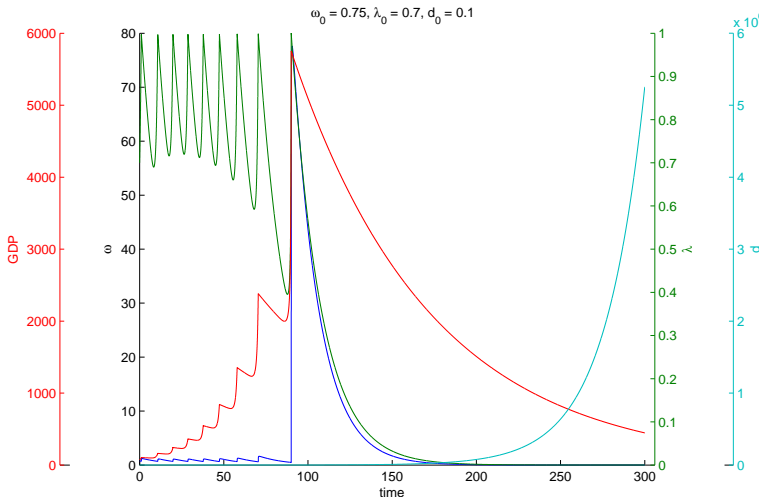
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Example 3 (continued): divergent Keen model

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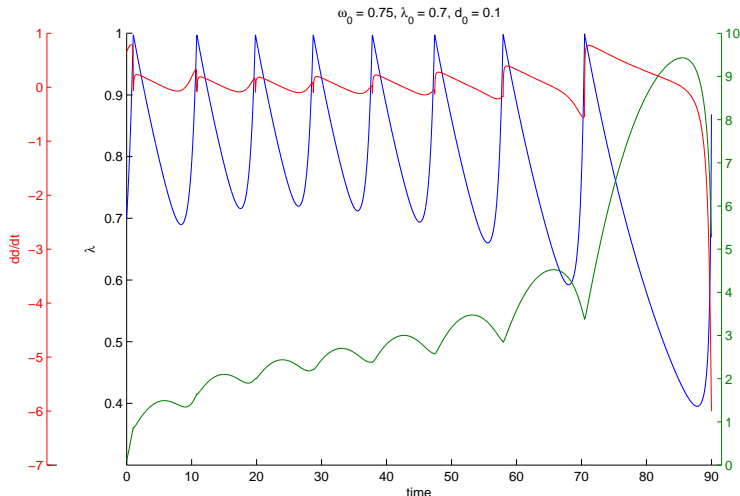
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Data detour: debt

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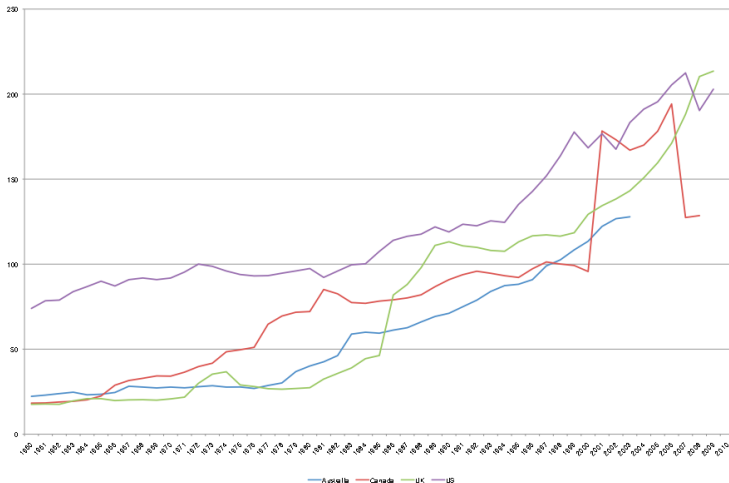
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Private Debt as % of GDP



Data detour: debt and employment

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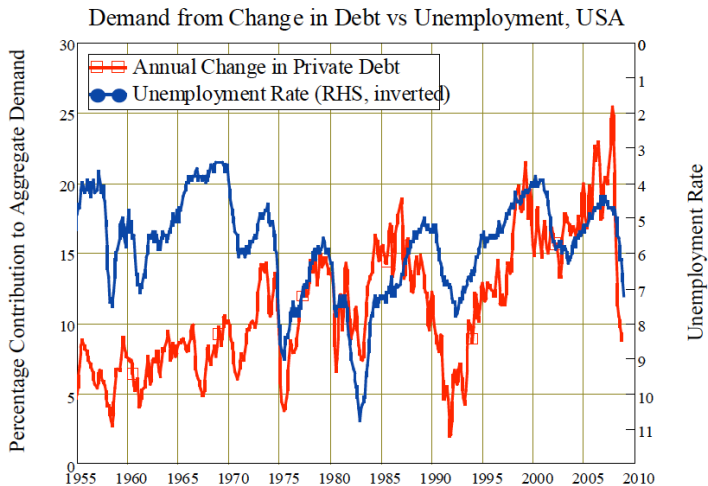


Figure: Source: Keen (2009)

Keen model - Local stability

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- Analyzing the Jacobian of (7) and (11) we obtain the following conclusions.
- The good equilibrium $(\bar{\omega}_1, \bar{\lambda}_1, \bar{d}_1)$ is stable if and only if

$$r \left[\kappa'(\bar{\pi}_1) \left(\frac{\bar{\pi}_1}{\nu} - \delta \right) - (\alpha + \beta) \right] > 0.$$

- The second equilibrium $(0, 0, \bar{d}_2)$ is unstable whenever

$$\kappa(1 - r\bar{d}_2) > \kappa(1 - \bar{\omega}_1 - r\bar{d}_1)$$

- The third equilibrium $(0, \lambda, \bar{d}_1)$ is structurally unstable.
- The point $(0, 0, 0)$ is a stable equilibrium for (11) if and only if

$$\frac{\kappa_0}{\nu} < \min(\alpha + \beta + \delta, r + \delta)$$

Basin of convergence for Keen model

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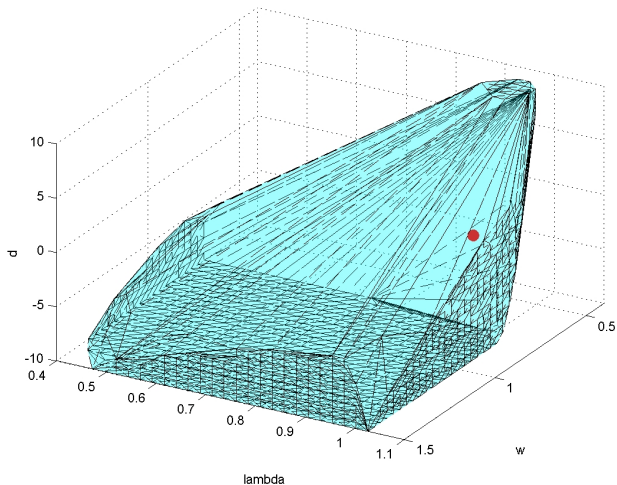
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To introduce the destabilizing effect of purely speculative investment, Keen (2009) considers a modified version of the previous model with

$$\begin{aligned}\dot{D} &= \kappa(1 - \omega - rd)Y - (1 - \omega - rd)Y + P \\ \dot{P} &= \Psi(g)Y\end{aligned}$$

where $\Psi(\cdot)$ is an increasing function of the growth rate of economic output

$$g = \frac{\kappa(1 - \omega - rd)}{\nu} - \delta.$$

Ponzi financing - Differential equations

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Denoting $\Psi(\omega, d) = \Psi\left(\frac{\kappa(1-\omega-rd)}{\nu} - \delta\right)$, the system now becomes

$$\dot{\omega} = \omega \left[\frac{\phi_1}{(1-\lambda)^2} - (\alpha + \phi_0) \right]$$

$$\dot{\lambda} = \lambda \left[\frac{\kappa(1-\omega-rd)}{\nu} - \alpha - \beta - \delta \right]$$

$$\dot{d} = d \left[r - \frac{\kappa(1-\omega-rd)}{\nu} + \delta \right] + \kappa(1-\omega-rd) - (1-\omega) + p$$

$$\dot{p} = \Psi(\omega, d) - \left(\frac{\kappa(1-\omega-rd)}{\nu} - \delta \right) p$$

Ponzi financing - Equilibria

- The finite debt equilibrium for the new system has $\bar{\pi}_1$ and $\bar{\lambda}_1$ as before, but

$$\bar{\omega}_1 = 1 - \bar{\pi}_1 - r\bar{d}_1$$

$$\bar{d}_1 = \frac{\nu(\alpha + \beta + \delta) - \bar{\pi}_1 + \bar{p}_1}{\alpha + \beta}$$

$$\bar{p}_1 = \frac{\Psi(\alpha + \beta)}{\alpha + \beta}$$

and is now unstable for typical model parameters.

- On the other hand, introducing $u = 1/d$ and $v = 1/p$ we find that

$$(\omega, \lambda, d, p) = (0, 0, +\infty, -\infty)$$

$$(\omega, \lambda, d, p) = (0, 0, +\infty, +\infty)$$

correspond to stable equilibria for the modified system.

Example 4: effect of Ponzi financing

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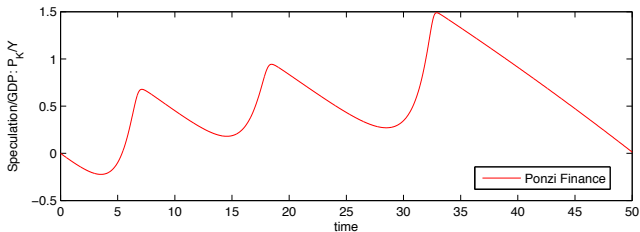
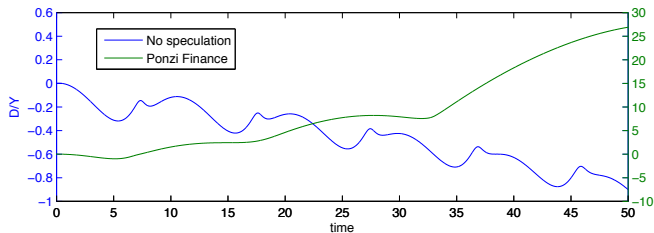
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Introducing a government sector

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- A final extension proposed by Keen (echoing Minsky) consists of adding government spending and taxation into the original system according to

$$\dot{G} = \Gamma(\lambda)Y$$

$$\dot{T} = \Theta(\pi)Y$$

- Defining $g = G/Y$ and $t = T/Y$, the net profit share is now

$$\pi = 1 - \omega - rd + g - t$$

- The new 5-dimensional system displays more local fluctuations, but no breakdown for the same initial conditions as before.

Example 5: stabilizing government

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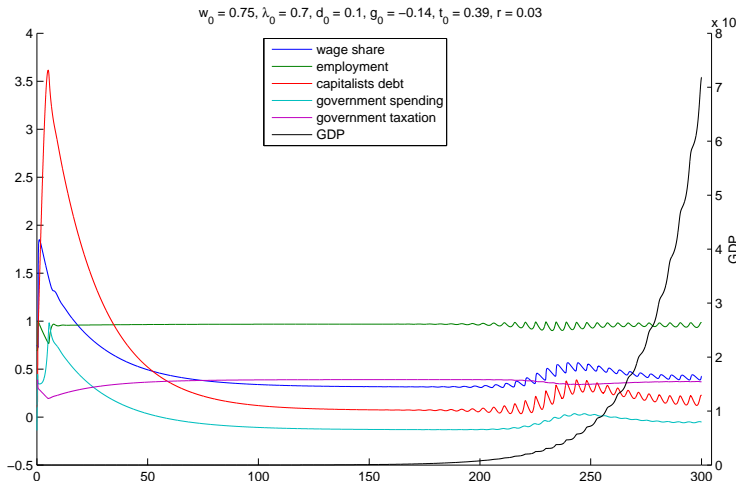
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Example 5 (continued): stabilizing government

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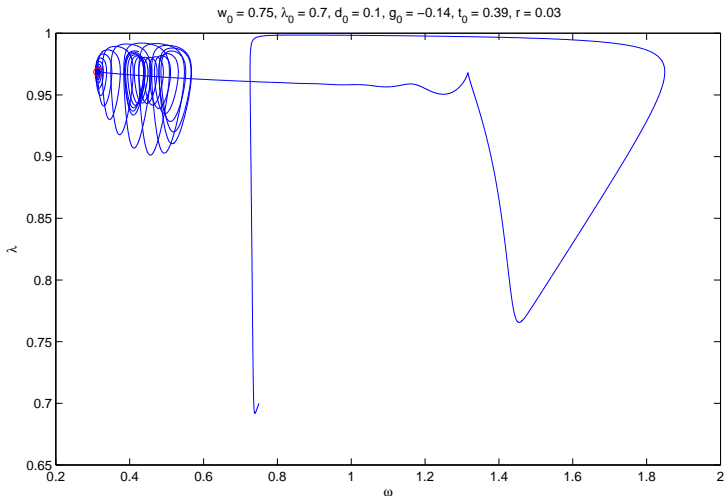
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Next steps

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- Model prices for capital goods P_k and commodities P_c explicitly (Kaleckian mark-up theory, inflation, etc)
- Introduce noise (stochastic interest rates, risk premium, etc)
- Calibrate to macroeconomic time series.

Concluding thoughts

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- Solow (1990): The true test of a simple model is whether it helps us to make sense of the world. Marx was, of course, dead wrong about this. We have changed the world in all sorts of ways, with mixed results; the point is to interpret it.
- Schumpeter (1939): Cycles are not, like tonsils, separable things that might be treated by themselves, but are, like the beat of the heart, of the essence of the organism that displays them.