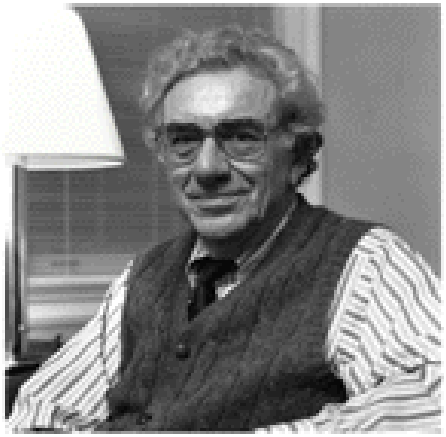
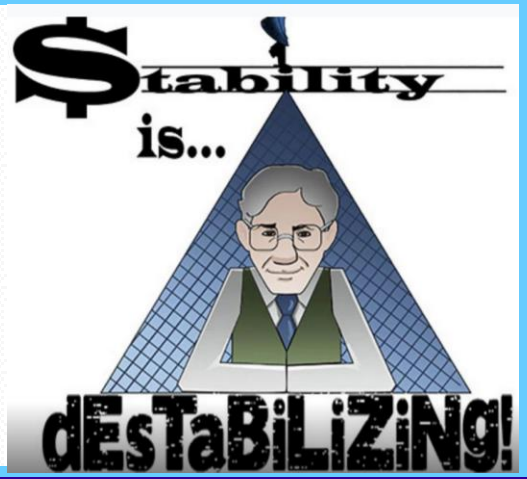
Kingston University London





Monetary modelling & interplay with sustainability

Steve Keen

Kingston University London

IDEAeconomics

Minsky Open Source System Dynamics

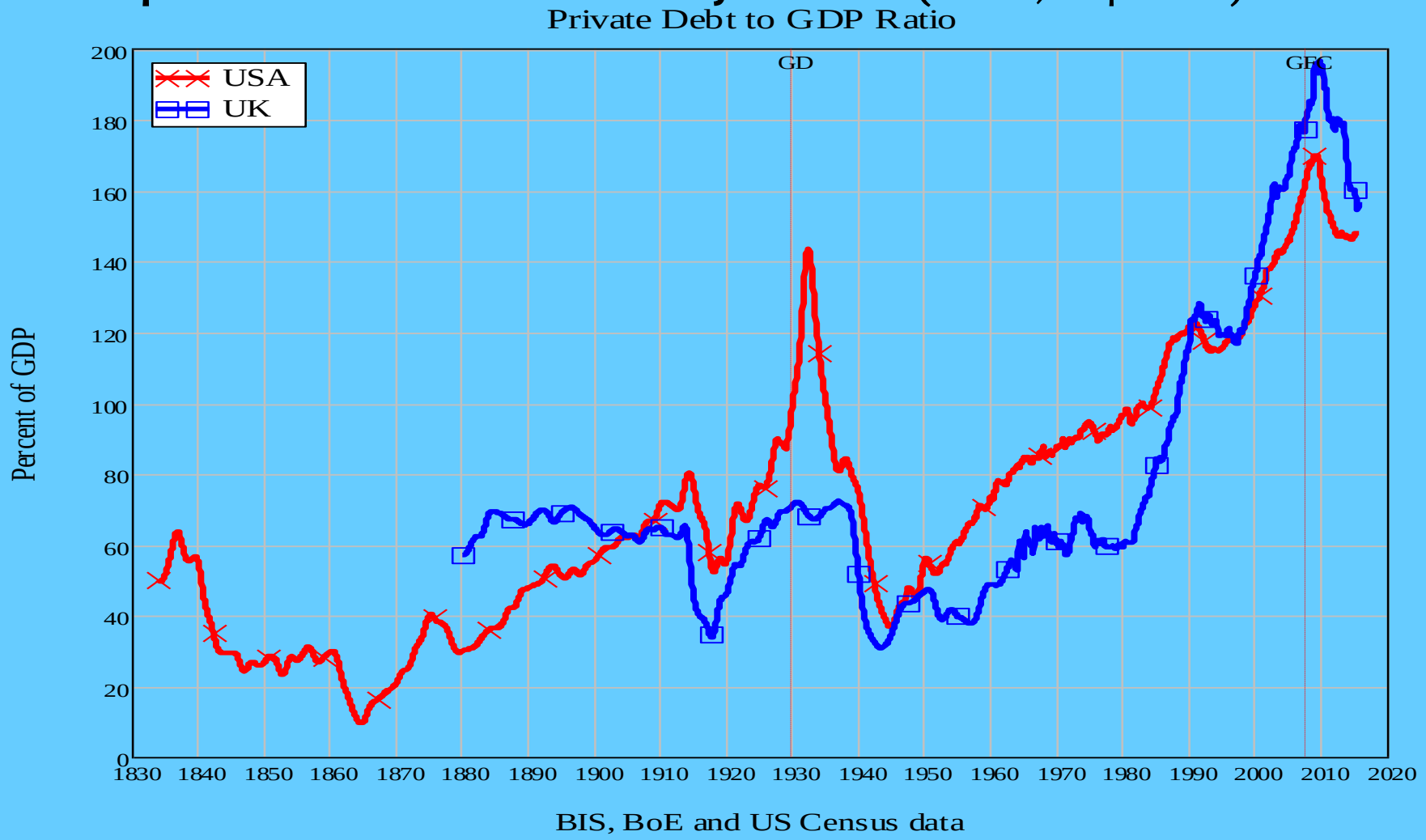
www.debtdeflation.com/blogs

Why does finance periodically dominate capitalism?

- "Military-Industrial Complex" the dominant corporations in 1950s-60s
- 1970s' expectation "Information Technology" would take over
- IT important, but in fact finance dominates (& IT serves finance)
- Might this be the reason why?:
  - "Talk about centralisation! The credit system, which has its focus in the so-called national banks and the big money-lenders and usurers surrounding them, constitutes enormous centralisation, and gives this class of parasites the fabulous power, not only to periodically despoil industrial capitalists, but also to interfere in actual production in a most dangerous manner—***and this gang knows nothing about production and has nothing to do with it***…
  - A high rate of interest can also indicate, as it did in 1857, that the country is undermined by the **roving cavaliers of credit** who can afford to pay a high interest because they pay it out of other people's pockets (whereby, however, they help to determine the rate of interest for all), and **meanwhile they live in grand style on anticipated profits**…

Why does finance periodically dominate capitalism?

- "Simultaneously, precisely this can incidentally provide a very profitable business for manufacturers and others. **Returns become wholly deceptive as a result of the loan system…**" (Marx, Capital II)



Why does finance periodically dominate capitalism?

- Minsky identified a tendency towards debt crises in capitalism:
  - "The natural starting place for analyzing the relation between debt and income is to take an economy with a cyclical past that is now doing well.
  - The inherited debt reflects the history of the economy, which includes a period in the not too distant past in which the economy did not do well.
  - Acceptable liability structures are based upon some margin of safety so that expected cash flows, even in periods when the economy is not doing well, will cover contractual debt payments.
  - As the period over which the economy does well lengthens, two things become evident in board rooms. Existing debts are easily validated and units that were heavily in debt prospered; it paid to lever… it follows that *the fundamental instability of a capitalist economy is upward. The tendency to transform doing well into a speculative investment boom is the basic instability in a capitalist economy.*" {Minsky, 1977 #221, pp. 10,13}

Modeling credit in capitalism

- My Minsky model can be derived by from 3 definitions in dynamic form:
  - Employment rate L/N=λ;
  - Wages share of GDP W/Y=ω;
  - Private debt to GDP ratio d=D/Y

- "Employment will rise if economic growth exceeds the sum of population & labor productivity growth"

$$\frac{1}{\lambda}\frac{d}{dt}\lambda \equiv \hat{\lambda} \equiv \hat{Y}_R - \left(\hat{a} + \hat{N}\right)$$

- "Wages share of output will rise if wage rise exceeds growth in labor productivity"

$$\frac{1}{\omega}\cdot\frac{d}{dt}\omega = \hat{\omega} \equiv \hat{w}_R - \hat{a}$$

- "Debt ratio will rise if rate of growth of debt exceeds rate of growth of GDP"

$$\frac{1}{d}\cdot\frac{d}{dt}d = \hat{d} \equiv \hat{D} - \hat{Y}_R$$

From periodic cycles to complexity

- Operationalise with simplest possible expressions for Y_R, W_R, D:
  - Output a linear function of capital
  - Labour a linear function of output

$$Y_R = \frac{K_R}{v} = a \cdot L$$

$$\hat{Y}_R = \frac{1}{\frac{K_R}{v}}\left(\frac{d}{dt}\frac{K_R}{v}\right) = \frac{1}{K_R}\cdot\left(I_R\right) - \frac{1}{K_R}\cdot\left(I_{G_R} - \delta_{K_R}\cdot K_R\right)$$

- Output growth a function of investment & depreciation

- Gross investment a function of rate of profit

$$\frac{I_{G_R}}{Y_R} = \pi_S \cdot \left(\frac{\Pi_R}{Y_R} - \pi_Z\right)$$

$$\Pi_R = Y_R - w_R \cdot L - r \cdot D$$

- Change in debt is investment minus profits

$$\hat{D} = I_R - \Pi_R$$

- Linear Phillips curve

$$\hat{w}_R\left(\lambda\right) = \lambda_S \cdot \left(\lambda - \lambda_Z\right)$$

- Exponential population & productivity growth $\left(\hat{a} + \hat{N}\right) = \alpha + \beta$

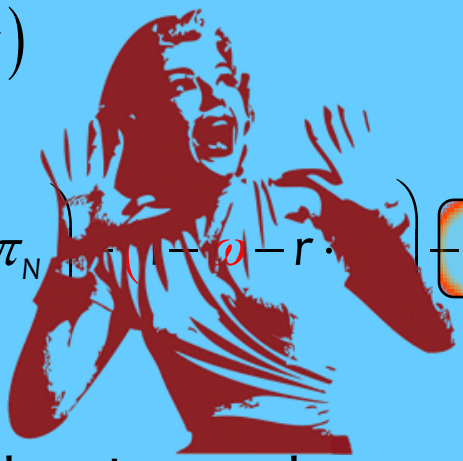
From periodic cycles to complexity

- From all that, we get this system

$$\dot{\lambda} = \lambda \cdot \left(\frac{\pi_S \cdot \left(\frac{1 - \omega - r \cdot d}{v} - \pi_N \right)}{v} - (\alpha + \beta + \delta_{KR}) \right)$$

$$\dot{\omega} = \omega \cdot (\lambda_S \cdot (\lambda - \lambda_N) - \alpha)$$

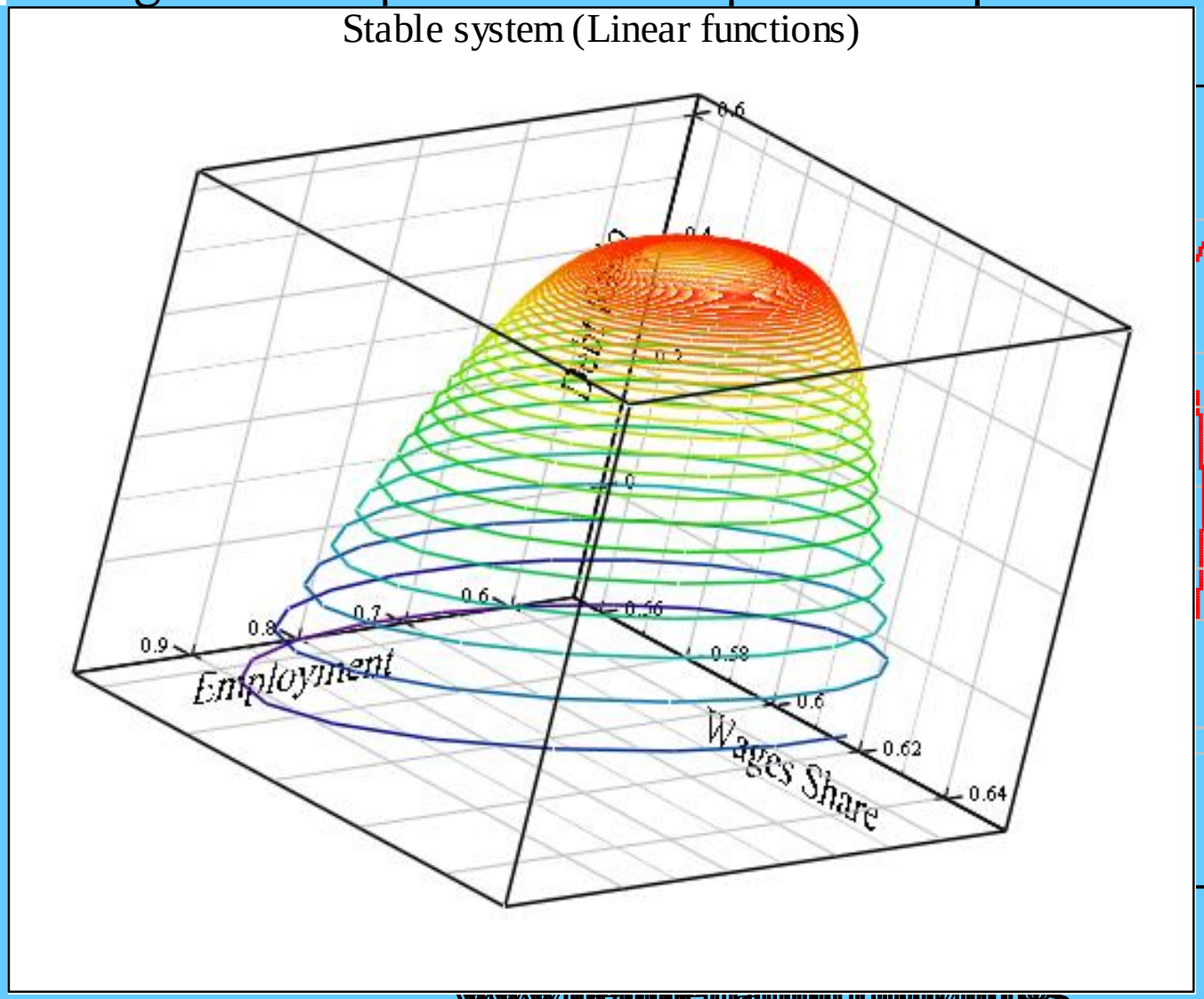
$$\dot{d} = \left(\pi_S \cdot \left(\frac{1 - \omega - r \cdot d}{v} - \pi_N \right) - (\alpha + \beta + \delta_{KR}) \right) \cdot d$$



- More parameters than Lorenz because, but same core components
  - 3 equations—so potential for chaotic behaviour
  - Inherent nonlinearities: one variable multiplied by another
- System this simple shouldn't tell us anything profound about capitalism
- But it does… Three equilibria; and peculiar path towards them…

From periodic cycles to complexity

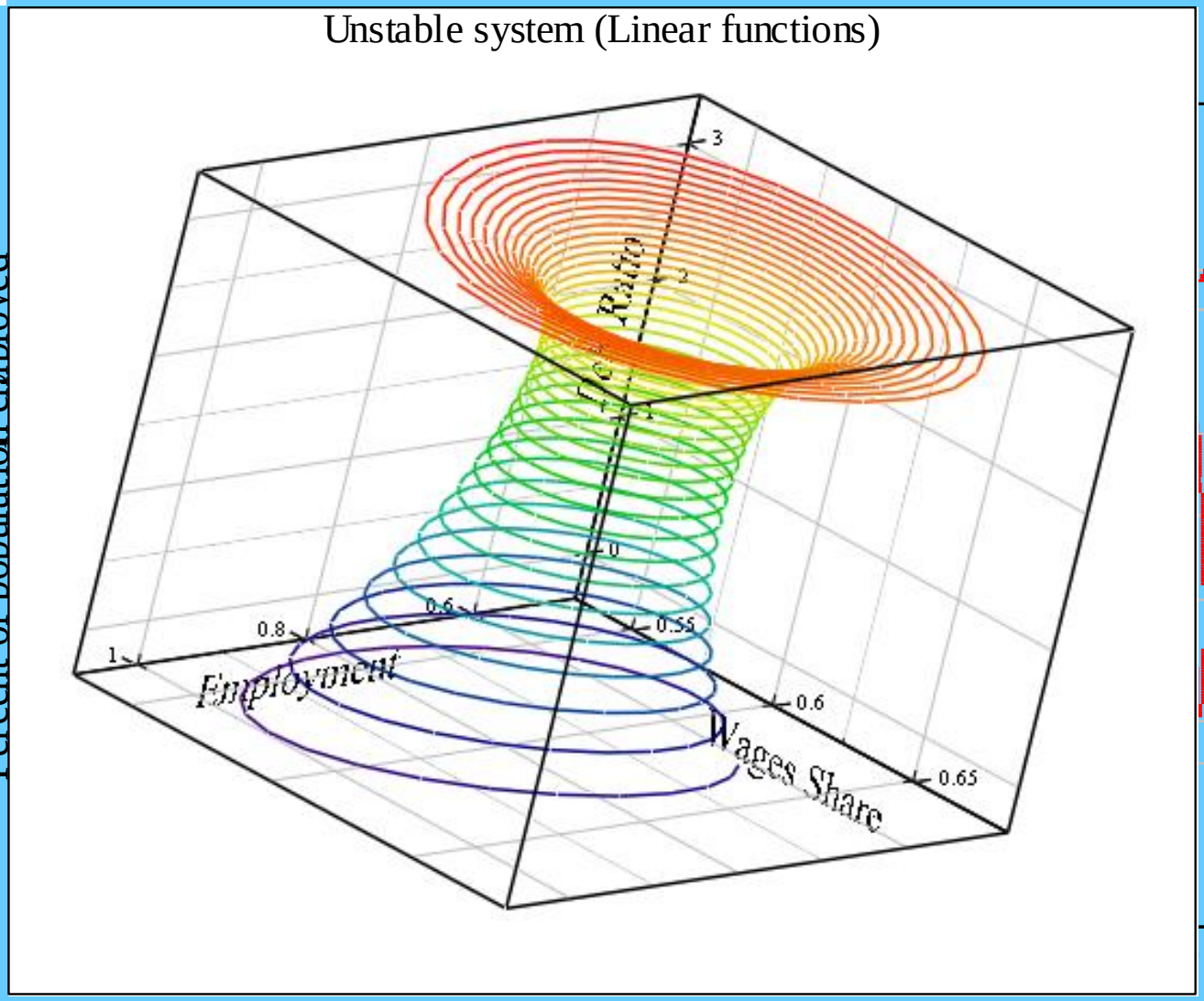
- Convergence to equilibrium with "passive" capitalists

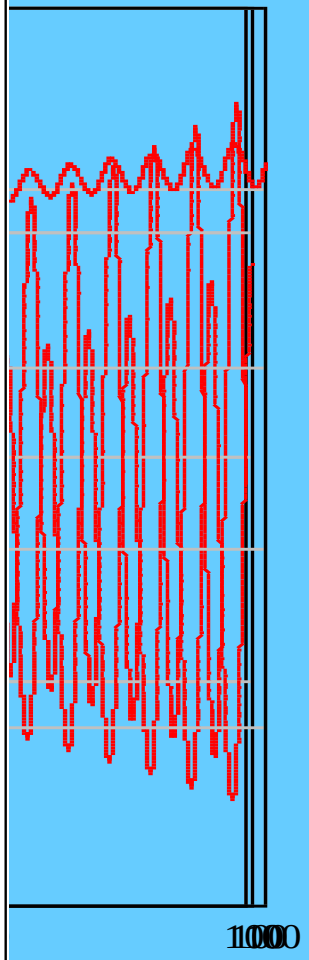


Stable

From periodic cycles to complexity

- (2) Convergence to "bad" equilibrium ***after apparent "moderation"***

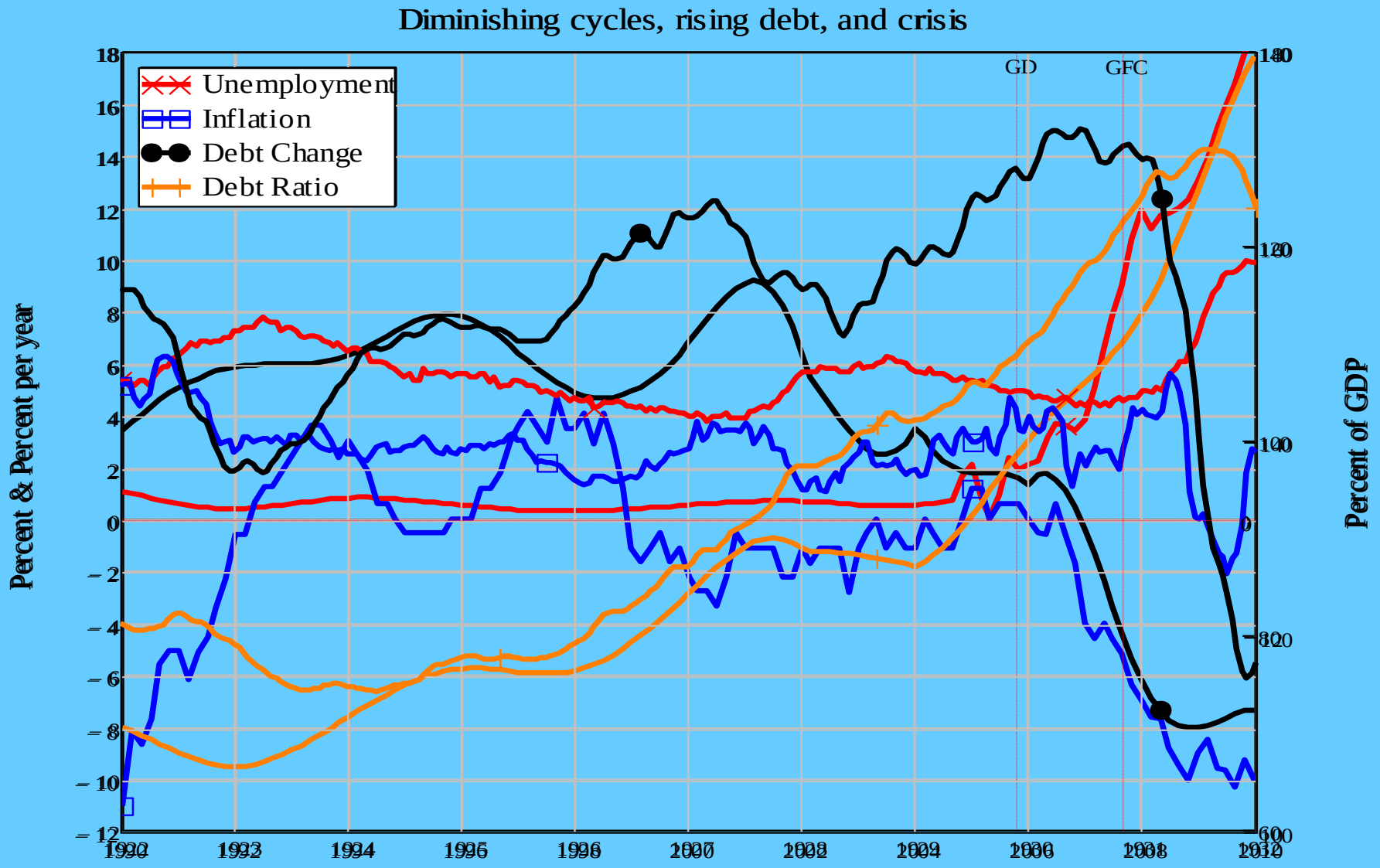




Unstable

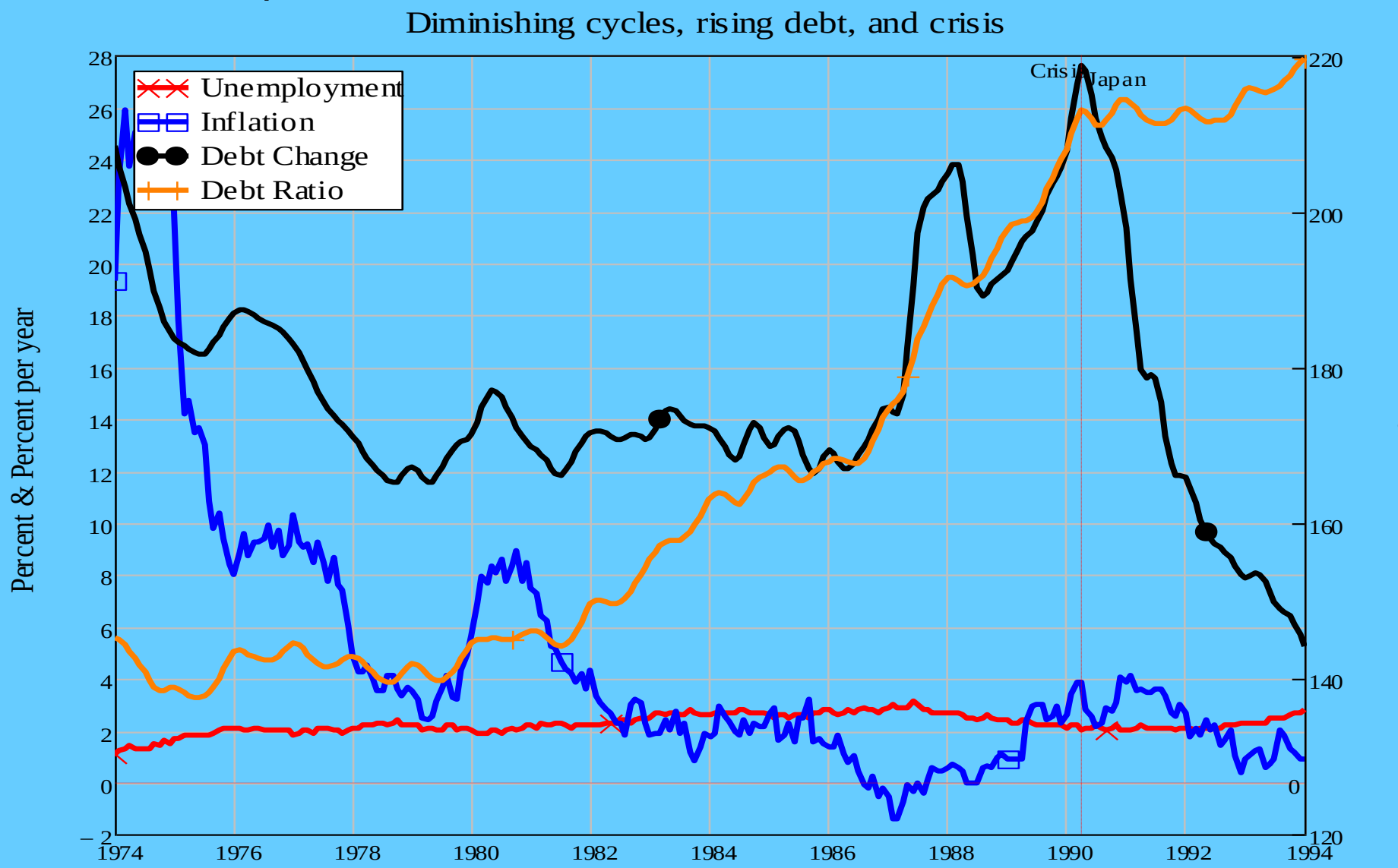
From periodic cycles to complexity

- Which pattern applies in the real world? The USA 1920-40 & 1990-2010



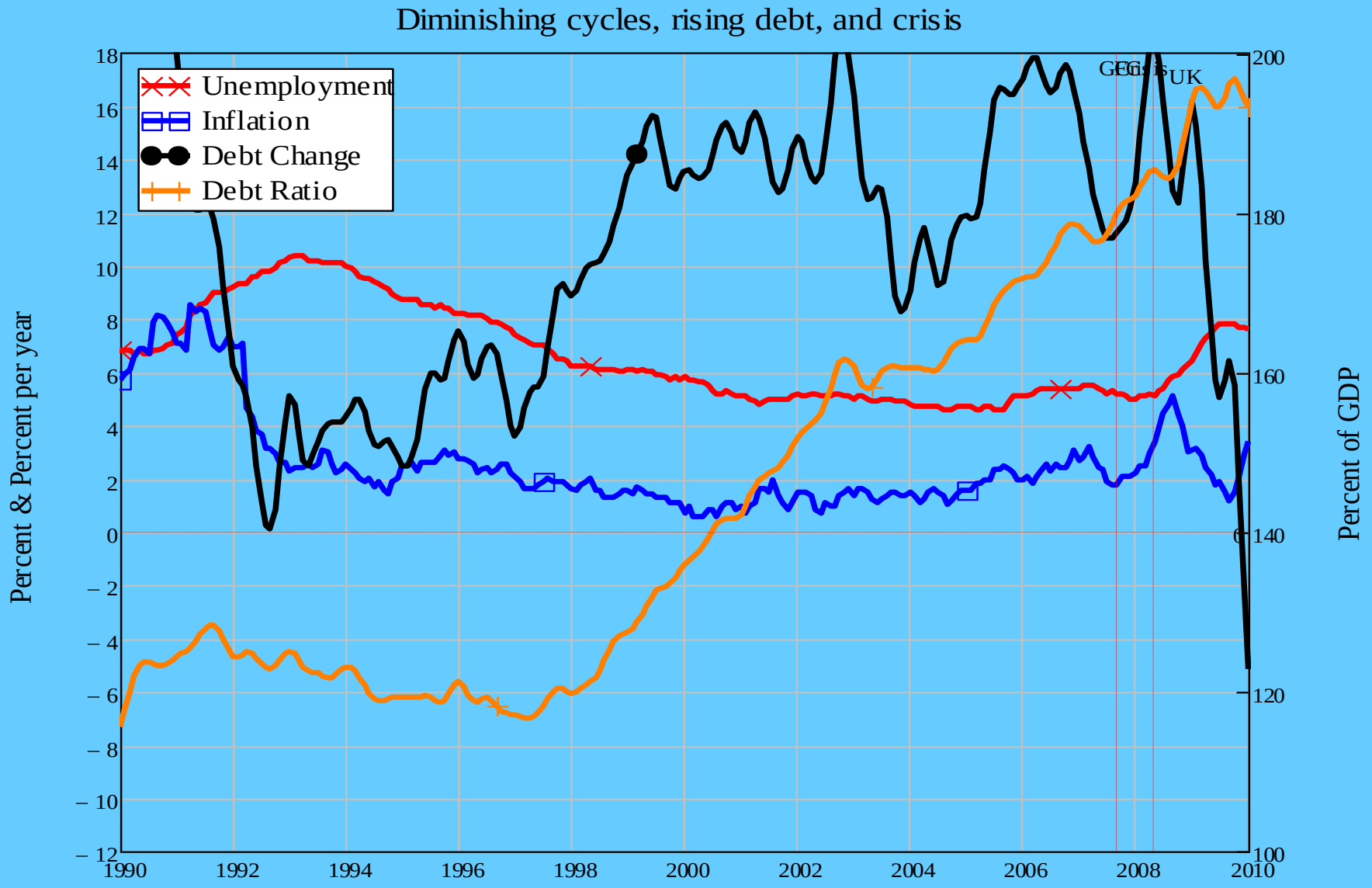
From periodic cycles to complexity

- Same in Japan…



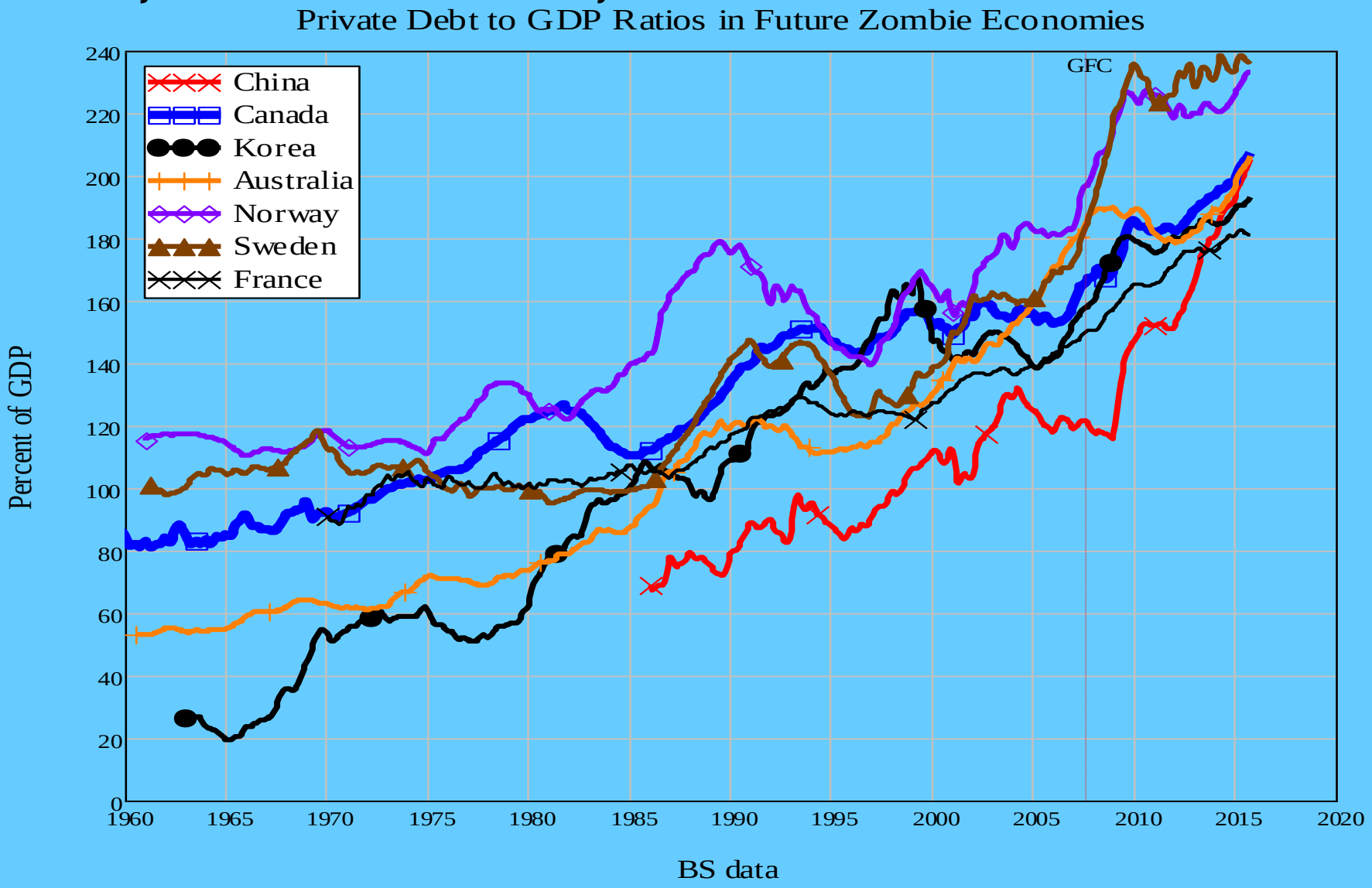
From periodic cycles to complexity

- Similar in UK



From periodic cycles to complexity

- Many countries that haven't yet had a debt crisis are headed for one



From periodic cycles to complexity

- Lower growth rate with higher propensity to invest—higher debt level
- Strong sensitivity of debt to slope of investment function
- Bankers benefit at expense of capitalists, workers
- Higher desire to invest, lower growth rate

Parameters

$\pi_S := 5$ $\pi_Z := 3\%$

$\lambda_S := 10$ $\lambda_Z := 60\%$

$\alpha := 2\%$ $\beta := 1\%$ $\delta_{KR} := 6\%$ $v := 3$ $r := 4\%$

Equilibria given parameters

$$\lambda_{Eq} := \left(\frac{\alpha}{\lambda_S} + \lambda_Z\right) = 60.2\%$$

$$\pi_{sEq} := v \cdot \left[\frac{v \cdot (\alpha + \beta + \delta_{KR})}{\pi_S} + \pi_Z\right] = 25.2\%$$

$$d_{Eq} := \frac{v \cdot (\alpha + \beta + \delta_{KR}) - v \cdot \left[\frac{v \cdot (\alpha + \beta + \delta_{KR})}{\pi_S} + \pi_Z\right]}{\alpha + \beta} = 60\%$$

So bankers share is $b_{Eq} := r \cdot d_{Eq}$

$b_{Eq} = 2.4\%$

$\omega_{Eq} := 1 - \pi_{sEq} - b_{Eq} = 72.4\%$

Equilibrium growth rate

$$g_{Eq} := \frac{\frac{v \cdot (\alpha + \beta + \delta_{KR})}{\pi_S} + \pi_Z}{v} = 2.8\%$$

Parameters

$\pi_S := 6$ $\pi_Z := 3\%$

$\lambda_S := 10$ $\lambda_Z := 60\%$

$\alpha := 2\%$ $\beta := 1\%$ $\delta_{KR} := 6\%$ $v := 3$ $r := 4\%$

Equilibria given parameters

$$\lambda_{Eq} := \left(\frac{\alpha}{\lambda_S} + \lambda_Z\right) = 60.2\%$$

$$\pi_{sEq} := v \cdot \left[\frac{v \cdot (\alpha + \beta + \delta_{KR})}{\pi_S} + \pi_Z\right] = 22.5\%$$

$$d_{Eq} := \frac{v \cdot (\alpha + \beta + \delta_{KR}) - v \cdot \left[\frac{v \cdot (\alpha + \beta + \delta_{KR})}{\pi_S} + \pi_Z\right]}{\alpha + \beta} = 150\%$$

So bankers share is $b_{Eq} := r \cdot d_{Eq}$

$b_{Eq} = 6 \cdot \%$

$\omega_{Eq} := 1 - \pi_{sEq} - b_{Eq} = 71.5\%$

Equilibrium growth rate

$$g_{Eq} := \frac{\frac{v \cdot (\alpha + \beta + \delta_{KR})}{\pi_S} + \pi_Z}{v} = 2.5\%$$

From periodic cycles to complexity

- Same effects from lower desired level of profits:

Parameters

$\pi_S := 6$ $\pi_Z := 4\%$

$\lambda_S := 10$ $\lambda_Z := 60\%$

$\alpha := 2\%$ $\beta := 1\%$ $\delta_{KR} := 6\%$ $v := 3$ $r := 4\%$

Equilibria given parameters

$$\lambda_{Eq} := \left(\frac{\alpha}{\lambda_S} + \lambda_Z\right) = 60.2\%$$

$$\pi_{sEq} := v \cdot \left[\frac{v \cdot (\alpha + \beta + \delta_{KR})}{\pi_S} + \pi_Z\right] = 25.5\%$$

$$d_{Eq} := \frac{v \cdot (\alpha + \beta + \delta_{KR}) - v \cdot \left[\frac{v \cdot (\alpha + \beta + \delta_{KR})}{\pi_S} + \pi_Z\right]}{\alpha + \beta} = 50\%$$

So bankers share is $b_{Eq} := r \cdot d_{Eq}$

$b_{Eq} = 2 \cdot \%$

$\omega_{Eq} := 1 - \pi_{sEq} - b_{Eq} = 72.5\%$

Equilibrium growth rate

$$g_{Eq} := \frac{\frac{v \cdot (\alpha + \beta + \delta_{KR})}{\pi_S} + \pi_Z}{v} = 2.833\%$$

Parameters

$\pi_S := 6$ $\pi_Z := 3\%$

$\lambda_S := 10$ $\lambda_Z := 60\%$

$\alpha := 2\%$ $\beta := 1\%$ $\delta_{KR} := 6\%$ $v := 3$ $r := 4\%$

Equilibria given parameters

$$\lambda_{Eq} := \left(\frac{\alpha}{\lambda_S} + \lambda_Z\right) = 60.2\%$$

$$\pi_{sEq} := v \cdot \left[\frac{v \cdot (\alpha + \beta + \delta_{KR})}{\pi_S} + \pi_Z\right] = 22.5\%$$

$$d_{Eq} := \frac{v \cdot (\alpha + \beta + \delta_{KR}) - v \cdot \left[\frac{v \cdot (\alpha + \beta + \delta_{KR})}{\pi_S} + \pi_Z\right]}{\alpha + \beta} = 150\%$$

So bankers share is $b_{Eq} := r \cdot d_{Eq}$

$b_{Eq} = 6 \cdot \%$

$\omega_{Eq} := 1 - \pi_{sEq} - b_{Eq} = 71.5\%$

Equilibrium growth rate

$$g_{Eq} := \frac{\frac{v \cdot (\alpha + \beta + \delta_{KR})}{\pi_S} + \pi_Z}{v} = 2.5\%$$

Integrating Credit into Income ≡ Expenditure

- Mainstream ignores credit because of "Loanable Funds"
  - "Think of it this way: when debt is rising, ***it's not the economy as a whole borrowing more money***.
  - It is, rather, a case of less patient people—people who for whatever reason want to spend sooner rather than later—borrowing from more patient people." (Krugman 2012, pp. 146-47)
- Macro role for credit still not accepted in Post Keynesian economics
  - "In this primer we will examine the macroeconomic theory that is the basis for analysing the economy as it actually exists. ***We begin with simple macro accounting, starting from the recognition that at the aggregate level spending equals income***." (Wray 2011)
  - "Unless Keen (2014a) can explain how a purchase of a good or service does not provide income for the seller, then he should rethink his claim that debt extensions can force an inequality between expenditure and income at the aggregate level…
  - a sector can spend more than its current income, but the sum of sectors cannot." (Fiebiger 2014, p. 296)

Integrating Credit into Income ≡ Expenditure

- An expenditure table view:
  - Divide economy into 3 non-bank sectors plus banking sector
  - Aggregate Expenditure negative sum of diagonal
  - Aggregate Income positive sum of off-diagonal elements
  - All flows (in $/Year) shown in lowercase
  - All stocks (in $) shown in uppercase
  - Greek ρ used for interest rate
  - First case: lending/borrowing does not occur:

	Assets	Liabilities			Equity
	Loans	S_1	S_2	S_3	B_E
	Level ($)	Flows ($/Year)			
S_1		a+b	a	b	
S_2		c	c+d	d	
S_3		e	f	e+f	
B_E					

$$AE = (a+b)+(c+d)+(e+f)$$

$$AY = a+b+c+d+e+f \equiv AE$$

Credit and Income ≡ Expenditure

- Loanable Funds and (almost) no role for credit
  - Sector 1 borrows ***l*** ($/Year) from Sector 2
  - Pays interest of ***ρ.L*** ($/Year) to Sector 2

	Assets	Liabilities			Equity
	Loans	S_1	S_2	S_3	B_E
	Level ($)	Flows ($/Year)			
S_1		a+b+l+ρ.L	a+ρ.L	b+l	
S_2		c	c+(d-l)	d-l	
S_3		e	f	e+f	
B_E					

$$AE = (a + b + \rho \cdot L) + (c + d) + (e + f)$$

$$AY = a + b + \rho \cdot L + c + d + e + f \equiv AE$$

Credit and Income ≡ Expenditure

- Endogenous Money and ***an essential*** role for credit
  - Sector 1 borrows ***I*** ($/Year) from banking sector
  - Pays interest of ***ρ.L*** ($/Year) to banking sector…

	Assets		Liabilities			Equity
	Loans		S_1	S_2	S_3	B_E
	Level ($)		Flows ($/Year)			
S_1	L	I	a+b+I+ρ.L	a	b+I	ρ.L
S_2			c	(c+d)	d	
S_3			e	f	(e+f)	
B_E			g	h	i	-(g+h+i

$$AE = (a + b + I + \rho \cdot L) + (c + d) + (e + f) + (g + h + i)$$

$$AY = a + b + I + \rho \cdot L + c + d + e + f + g + h + i \equiv AE$$

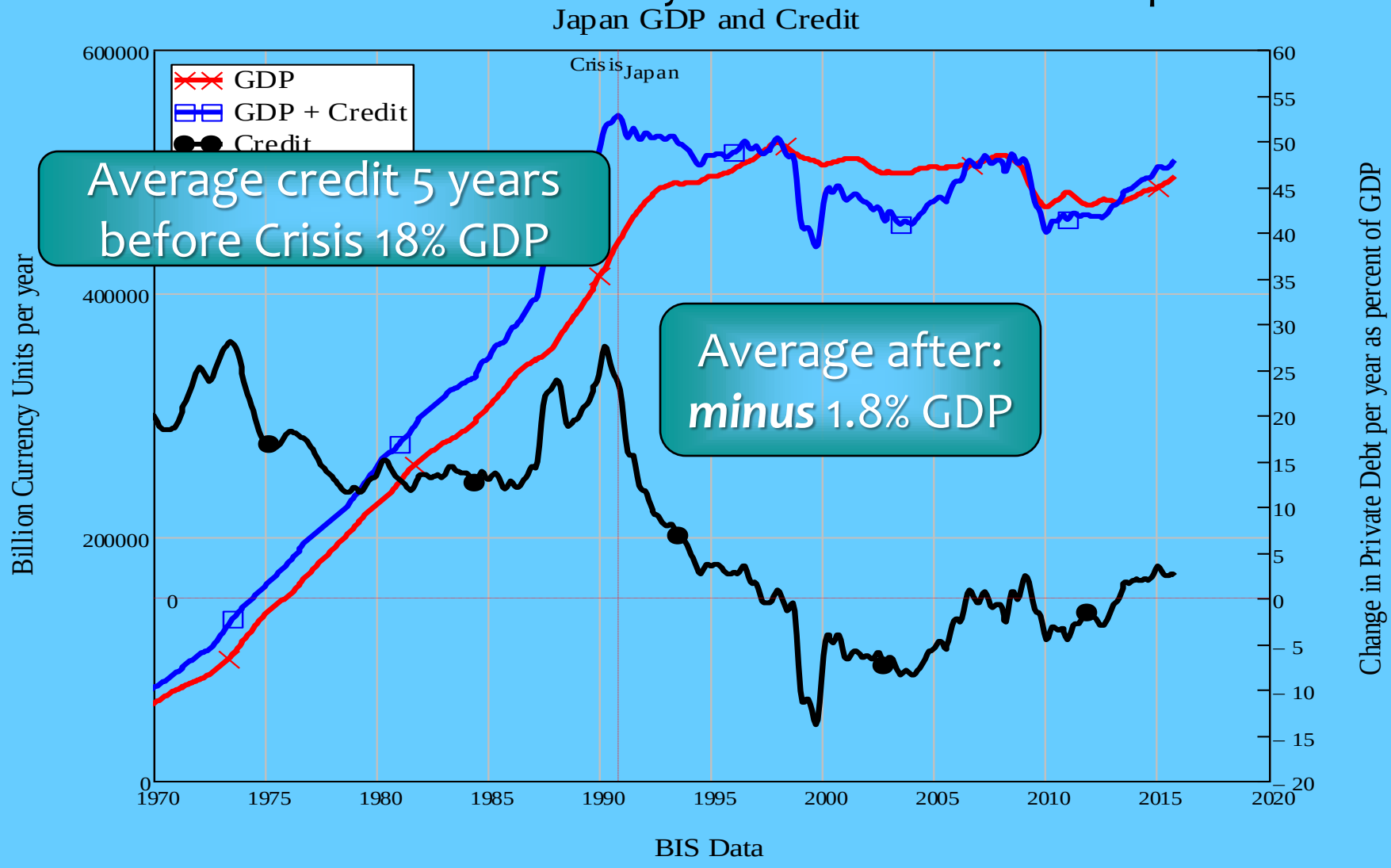
- Change in debt (≡credit) plays an ***essential*** role in aggregate expenditure & *aggregate income* with endogenous money
- Expenditure is fundamentally monetary
- 2 sources of expenditure: turnover of existing money
- New expenditure financed 1:1 by new debt

Credit and Income ≡ Expenditure

- How to measure?
  - GDP a (poor) approximate measure of flow of expenditure ***financed by existing money*** in $/Year
  - Change in debt a (better) measure of flow of credit ***created by new debt*** in $/Year
  - Dimensionally accurate & empirically OK to add together to measure aggregate expenditure at a point in time
  - Analogy
    - Flow in river
    - with a pump injecting or removing water:

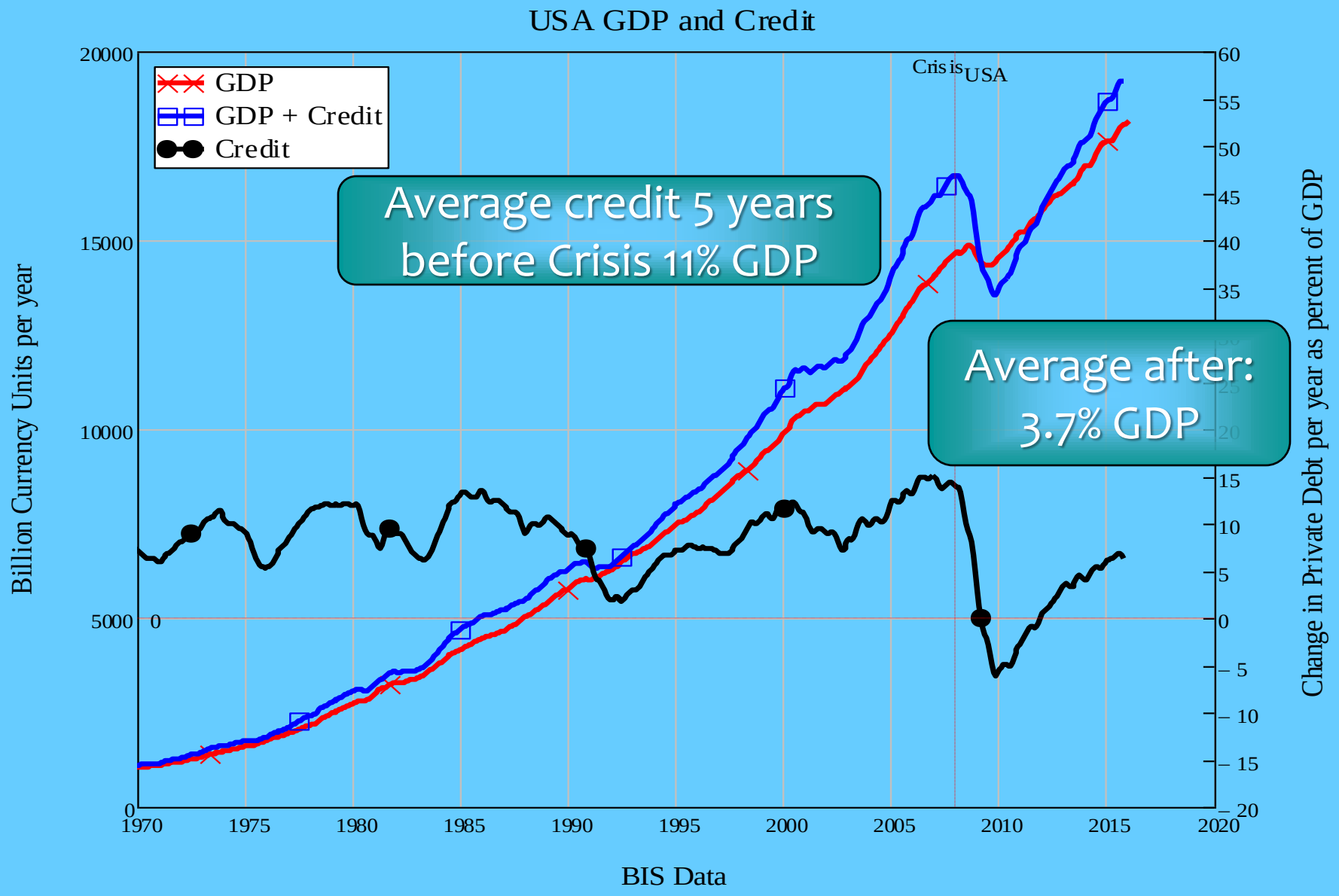
The "Smoking Gun of Credit" & Walking Dead of Debt

- Add GDP to change in debt (credit) to measure aggregate expenditure
- Peak GDP+Credit identifies every economic crisis since Japan…



The "Smoking Gun of Credit" & Walking Dead of Debt

- USA



Mainstream ignores private debt

- Lending as a "pure redistribution"; bank as intermediary

	Assets	Liabilities		Equity
	Reserves	**Saver**	**Investor**	**Bank**
Lending		From	To	
Paying interest		To	From	
Repaying		To	From	
Bank Fee for arranging loan		From		To

Nothing on Asset Side

Shuffling $ on Liability Side

- Lending as money creation; bank as originator of loans

	Assets		Liabilities		Equity
	Reserves	**Loans**	**Saver**	**Investor**	**Bank**
Lending		From		To	
Paying interest				From	To
Repaying		To		From	

Assets & Liabilities Rise

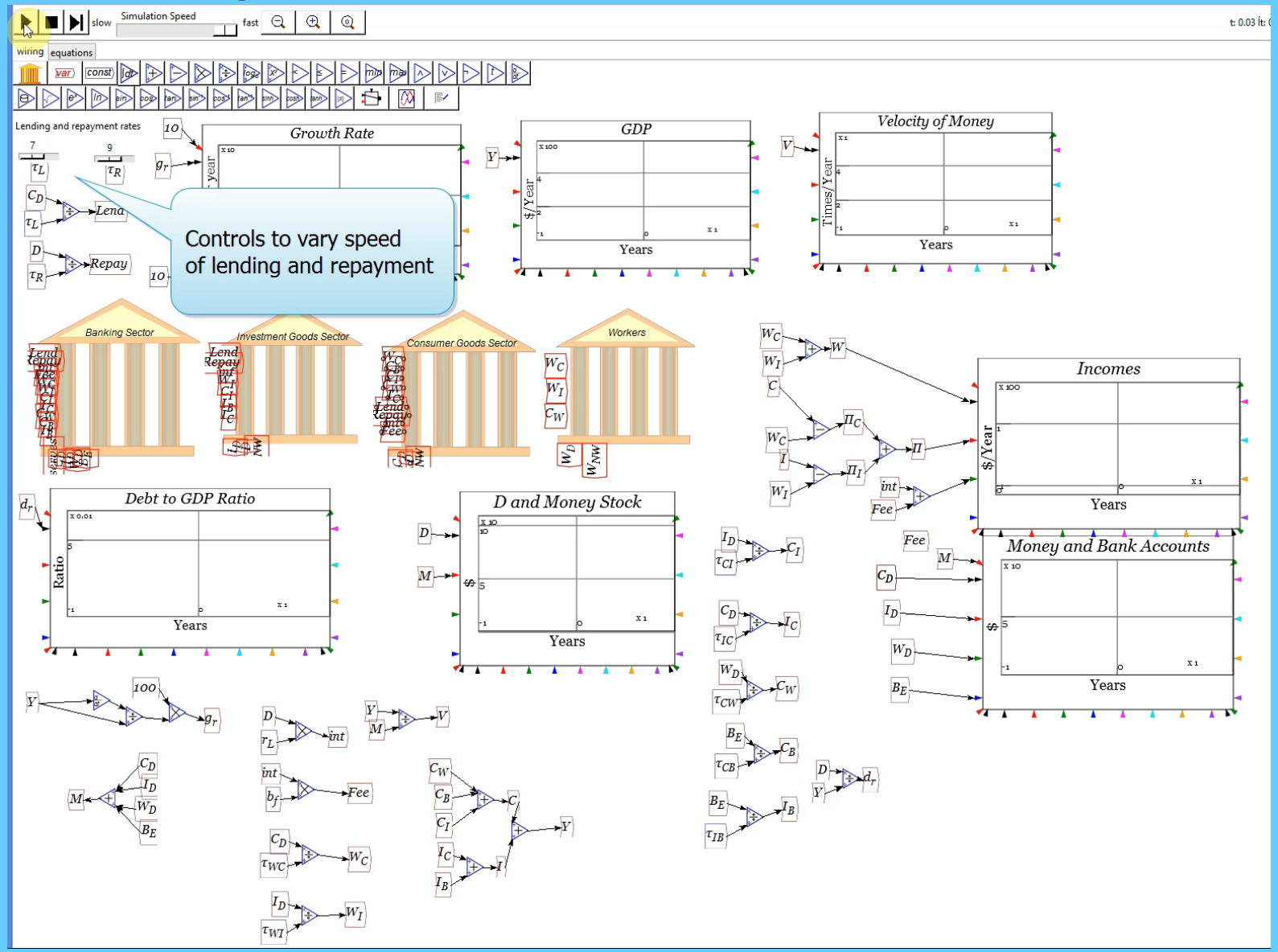
Assets & Liabilities Fall

- An essential difference…

Loanable Funds vs Endogenous Money

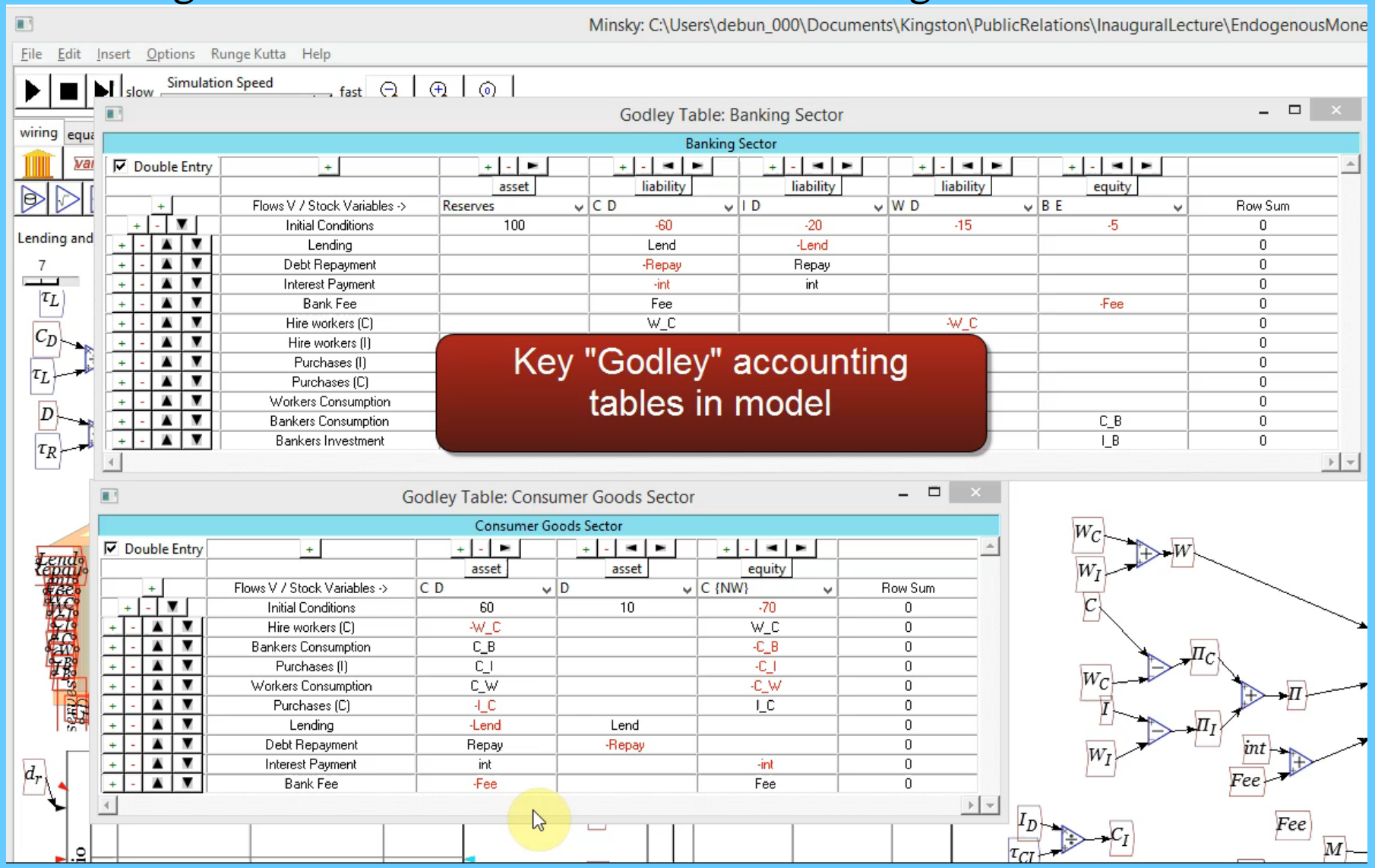
LoanableFunds.mky

- Modelling this in Minsky:



Loanable Funds vs Endogenous Money

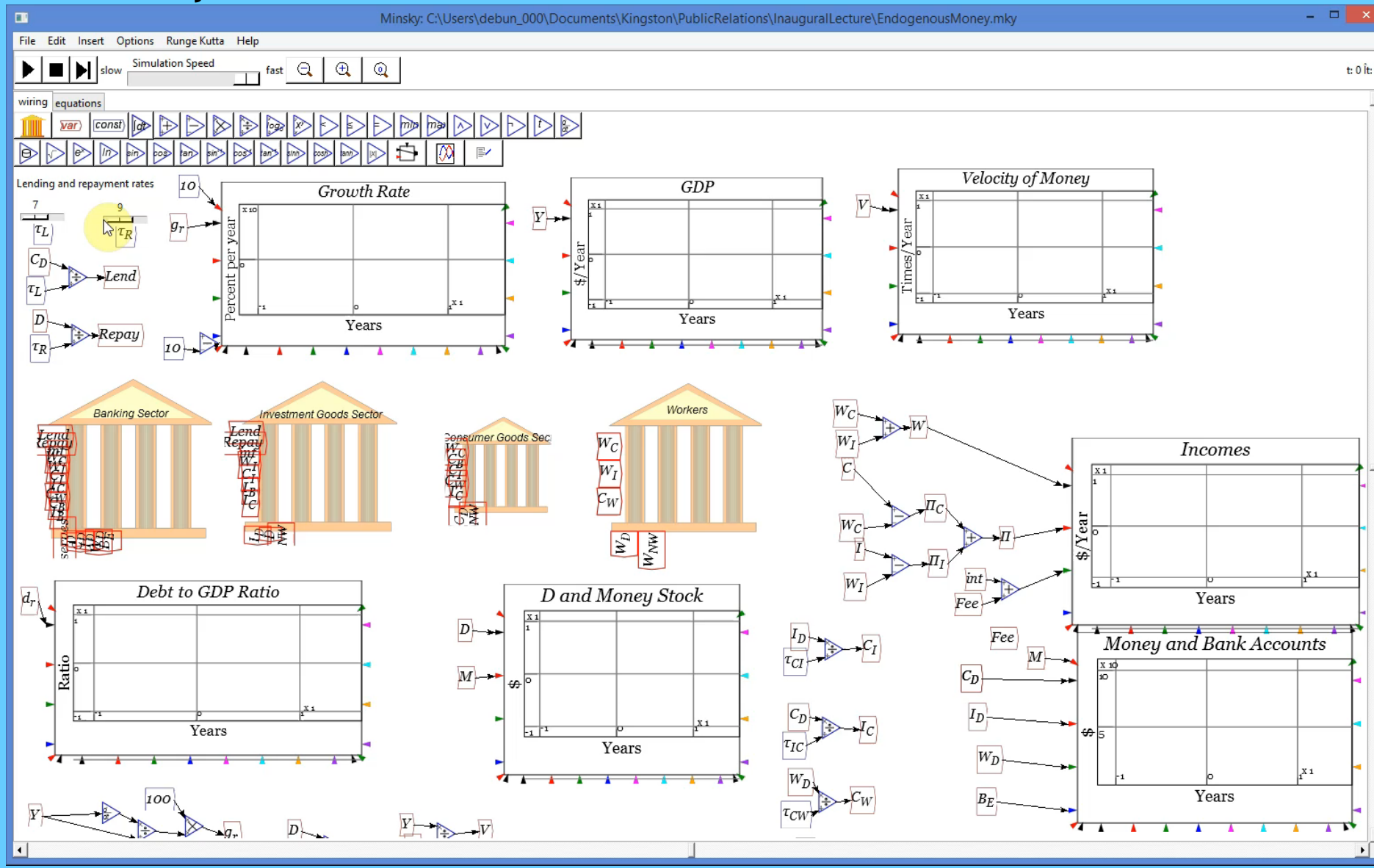
- Change banks from "Intermediators" to "Originators"



Loanable Funds vs Endogenous Money

EndogenousMoney.mky

- Is it any different?



Other features of Minsky

- Written in C++ & Tcl/Tk (didn't know of Modelica at the time—or knew of Xcos & didn't like it!)
- Live simulation with controls ("sliders", "switches")
  - Aim multi-user input to control single simulation
  - Showing need for coordinated "systems" approach to complex systems like economy & ecology
- Direct entry of equations onto canvas—no need to click on icons
- Support for LATEX—hence Greek letters, sub-superscripts, etc.
  - Converts system directly to LATEX for display/output
  - Intention to add each way model development
    - Flowchart to equations (as now)
    - Equations to flowcharts (future development)
- Future plans also include
  - Multi-sectoral vector model by "cloning" single sector scalar model
  - Multi-country by cloning single economy model
  - Monte-Carlo simulations & nonlinear parameter estimation
  - Redevelopment in Modelica?

A more complete Minsky model

- Still derived from identities:
  - The employment rate will rise if ***real*** economic growth exceeds the sum of population growth and growth in labor productivity;
  - The wages share of output will rise if ***money wage demands*** exceed the ***sum of inflation and growth in labor productivity***; and
  - The private debt to GDP ratio will rise if the rate of growth of private debt exceeds the ***sum of inflation plus the rate of economic growth.***
- Additional equations needed for
  - Rate of inflation
    - Lagged convergence to equilibrium prices in monetary economy
  - Variable nominal interest rate
    - Lagged inflation premium to base interest rate if inflation > 0

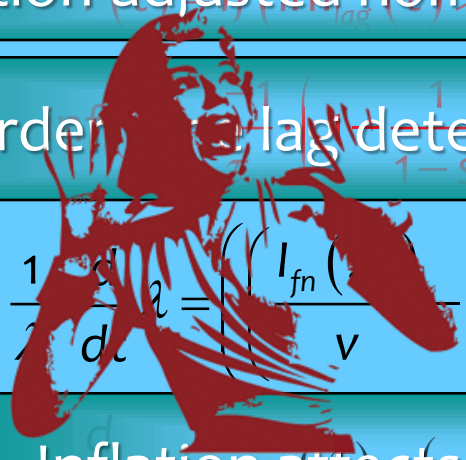
Simple complex systems model…

- Slightly more complicated *but still simple* model

$$\pi_s = 1 - \omega(t) - r(t)\cdot d(t); \pi_r = \frac{\pi_s}{v}$$

Inflation-adjusted nominal interest rate

1st order lag determines inflation



$$\frac{1}{\lambda}\frac{d\lambda}{dt} = \left(\left(\frac{I_{fn}(\pi_r)}{v} - \delta_{Kr}\right) - (\alpha+\beta)\right)$$

Inflation affects wages share

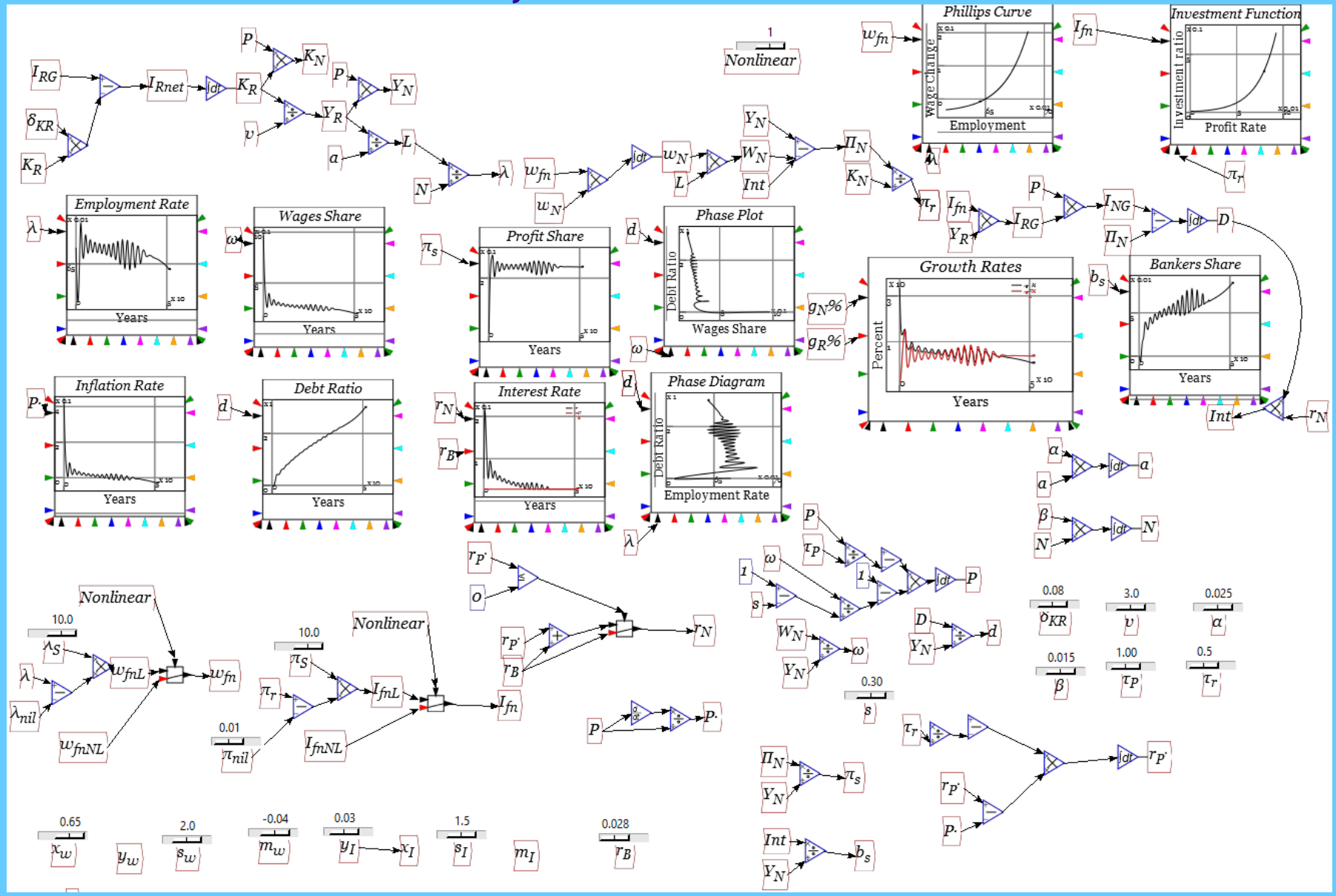
Inflation affects debt growth

Lagged interest rate reaction to inflation

Simple complex systems model…

MinskyPrivateOnlyBreakdown.mky

- The same model in Minsky:



Modelling role of energy in production

- Neoclassical: Cobb-Douglas production without energy

$$Y_R = L^{\alpha} \cdot K^{1-\alpha}$$

- Often energy suggested as third input…

$$Y_R = E^{\alpha} \cdot L^{\beta} \cdot K^{1-\alpha-\beta}$$

- Falsely implies energy can be completely omitted (just set α=0), but:
  - Labour without energy is a corpse
  - Capital without energy is a sculpture
- Suggestion: *show L and K as ways of harnessing "free" energy*
  - Both labour (L) and machines (K) turn embodied energy into work

$$Work_{ByLabor} = Labor \cdot EmbodiedEnergy_{Person} \cdot \frac{Exergy_{Person}}{EmbodiedEnergy_{Person}} \qquad W_L = L \cdot E_L \cdot \frac{Ex_L}{E_L} = L \cdot E_L \cdot e_l$$

$$Work_{ByMachines} = Machines \cdot EmbodiedEnergy_{Machine} \cdot \frac{Exergy_{Machine}}{EmbodiedEnergy_{Machine}} \qquad W_K = K \cdot E_K \cdot \frac{Ex_K}{E_K} = K \cdot E_K \cdot e_k$$

$$Y_R = W_L^{\alpha} \cdot W_K^{1-a} = \left(L \cdot E_L \cdot e_l\right)^{\alpha} \cdot \left(K \cdot E_K \cdot e_K\right)^{1-\alpha} = L^{\alpha} \cdot K^{1-\alpha} \cdot$$ Solow Residual

- Energy inputs of Labour effectively a constant
- Energy can no longer be substituted away—shares exponent of K
- Implies means to show waste as joint product; explains Solow Residual