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)
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 $L/N=\lambda$;
  - Wages share of GDP $W/Y=\omega$;
  - Private debt to GDP ratio $d=D/Y$

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

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

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

\[
\frac{1}{\lambda} \frac{d}{dt} \lambda \equiv \hat{\lambda} \equiv \dot{Y}_R - (\hat{a} + \hat{N})
\]

\[
\frac{1}{\omega} \frac{d}{dt} \omega = \hat{\omega} \equiv \dot{W}_R - \hat{a}
\]

\[
\frac{1}{d} \frac{d}{dt} d = \hat{d} \equiv \dot{D} - \dot{Y}_R
\]
From periodic cycles to complexity

- Operationalise with simplest possible expressions for $Y_R$, $W_R$, $D$:
  - Output a linear function of capital
    \[ Y_R = \frac{K_R}{v} = a \cdot L \]
  - Labour a linear function of output
    \[ \hat{Y}_R = \frac{1}{K_R} \left( \frac{d}{dt} \frac{K_R}{v} \right) = \frac{1}{K_R} \left( I_R \right) - \frac{1}{K_R} \left( I_{GR} - \delta_{KR} \cdot K_R \right) \]
  - Output growth a function of investment & depreciation

- Gross investment a function of rate of profit
  \[ I_{GR} = \pi_S \cdot \left( \frac{\Pi_R}{Y_R} - \pi_Z \right) \]
  \[ \Pi_R = Y_R - w_R \cdot L - r \cdot D \]

- Change in debt is investment minus profits
  \[ \hat{D} = I_R - \Pi_R \]

- Linear Phillips curve
  \[ \hat{\omega}_R (\lambda) = \lambda_S \cdot (\lambda - \lambda_Z) \]

- Exponential population & productivity growth
  \[ (\hat{a} + \hat{N}) = \alpha + \beta \]
From periodic cycles to complexity

- From all that, we get this system

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

\[
\dot{\omega} = \omega \cdot \left( \lambda_S \cdot (\lambda - \lambda_N) - \alpha \right)
\]

\[
\dot{d} = \left( \pi_S \cdot \left( 1 - \frac{\omega}{v} - r \cdot \frac{d}{v} - \pi_N \right) - \pi_N \right) - \delta_{KR}
\]

- 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 system (Linear functions)
From periodic cycles to complexity

• (2) Convergence to “bad” equilibrium after apparent “moderation”
From periodic cycles to complexity

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

**Diminishing cycles, rising debt, and crisis**
From periodic cycles to complexity

- Same in Japan...

Diminishing cycles, rising debt, and crisis

Unemployment, Inflation, Debt Change, Debt Ratio
From periodic cycles to complexity

- Similar in UK

Diminishing cycles, rising debt, and crisis

Percent & Percent per year

Percent of GDP

Unemployment
Inflation
Debt Change
Debt Ratio

GFC
Crisis
UK
From periodic cycles to complexity

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

Private Debt to GDP Ratios in Future Zombie Economies

- China
- Canada
- Korea
- Australia
- Norway
- Sweden
- France

Percent of GDP


BS data
### Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\pi_S$</td>
<td>6%</td>
</tr>
<tr>
<td>$\pi_Z$</td>
<td>3%</td>
</tr>
<tr>
<td>$\lambda_S$</td>
<td>10%</td>
</tr>
<tr>
<td>$\lambda_Z$</td>
<td>60%</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>2%</td>
</tr>
<tr>
<td>$\beta$</td>
<td>1%</td>
</tr>
<tr>
<td>$\delta_{KR}$</td>
<td>6%</td>
</tr>
<tr>
<td>$v$</td>
<td>3</td>
</tr>
<tr>
<td>$r$</td>
<td>4%</td>
</tr>
</tbody>
</table>

### Equilibria given parameters

**Bankers benefit at expense of capitalists, workers**

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

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

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

### 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
- Higher desire to invest, lower growth rate

So bankers share is $b_{Eq} = 6\%$

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So bankers share is $b_{Eq} = 6\%$
From periodic cycles to complexity

• Same effects from lower desired level of profits:

Equilibria given parameters

\[
\lambda_{Eq} := \left( \frac{\alpha}{\lambda_S} + \frac{\lambda}{\lambda_Z} \right) = 60.2\% \\
\pi_{sEq} := v \left[ \frac{v \left( \alpha + \beta + \delta_{KR} \right)}{\pi_S} + \pi_Z \right] = 25.5\% \\
d_{Eq} := \frac{v \left( \alpha + \beta + \delta_{KR} \right) - v \left[ \frac{v \left( \alpha + \beta + \delta_{KR} \right)}{\pi_S} + \pi_Z \right]}{\alpha + \beta} = 50\%
\]

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

\( b_{Eq} = 2.6\% \)

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

Equilibrium growth rate

\[
\bar{g}_{Eq} := \frac{v \left( \alpha + \beta + \delta_{KR} \right)}{\pi_S} + \pi_Z = 2.833\%
\]
Integrating Credit into Income $\equiv$ 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 $\rho$ used for interest rate
  - First case: lending/borrowing does not occur:

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
<th>Equity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loans</td>
<td>$S_1$</td>
<td>$S_2$</td>
</tr>
<tr>
<td></td>
<td>$B_E$</td>
<td></td>
</tr>
<tr>
<td>Level ($)</td>
<td>Flows ($/Year)</td>
<td></td>
</tr>
<tr>
<td>$S_1$</td>
<td>($a+b$)</td>
<td>$a$</td>
</tr>
<tr>
<td>$S_2$</td>
<td>$c$</td>
<td>($c+d$)</td>
</tr>
<tr>
<td>$S_3$</td>
<td>$e$</td>
<td>$f$</td>
</tr>
<tr>
<td>$B_E$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ AE = (a + b) + (c + d) + (e + f) \]

\[ AY = a + b + c + d + e + f \equiv AE \]
Credit and Income $\equiv$ Expenditure

- Loanable Funds and (almost) no role for credit
  - Sector 1 borrows $I$ ($/Year$) from Sector 2
  - Pays interest of $\rho L$ ($/Year$) to Sector 2

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</tr>
<tr>
<td>Level ($$)</td>
<td>Flows ($/Year$)</td>
<td></td>
</tr>
</tbody>
</table>

\[
\begin{align*}
S_1 & \quad (a+b+l+\rho L) & \quad a+\rho L & \quad b+l \\
S_2 & \quad c & \quad (c+(d-l)) & \quad d-l \\
S_3 & \quad e & \quad f & \quad (e+f) \\
B_E & \quad & \quad & \\
\end{align*}
\]

\[
AE = (a + b + \rho L) + (c + d) + (e + f) \\
AY = a + b + \rho L + c + d + e + f \equiv AE
\]
Credit and Income \equiv \text{Expenditure}

- Endogenous Money and \textit{an essential} role for credit
  - Sector 1 borrows \( l \) (\$/Year) from banking sector
  - Pays interest of \( \rho \cdot L \) (\$/Year) to banking sector...

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<tr>
<td>Level ($)</td>
<td>Flows ($/Year)</td>
<td></td>
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<tr>
<td>( S_1 )</td>
<td>L ( l )</td>
<td>( a+b+l+\rho \cdot L )</td>
</tr>
<tr>
<td>( S_2 )</td>
<td>( c )</td>
<td>( c+d )</td>
</tr>
<tr>
<td>( S_3 )</td>
<td>( e )</td>
<td>( f )</td>
</tr>
<tr>
<td>( B_E )</td>
<td>( g )</td>
<td>( h )</td>
</tr>
</tbody>
</table>

\[ AE = (a + b + l + \rho \cdot L) + (c + d) + (e + f) + (g + h + i) \]

\[ AY = a + b + l + \rho \cdot L + c + d + e + f + g + h + i \equiv AE \]

- Change in debt (\equiv credit) plays an \textit{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 $\equiv$ 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...

Japan GDP and Credit

Average credit 5 years before Crisis 18% GDP

Average after: minus 1.8% GDP

BIS Data

Change in Private Debt per year as percent of GDP

Billion Currency Units per year

GDP
GDP + Credit
Credit
The “Smoking Gun of Credit” & Walking Dead of Debt

USA

USA GDP and Credit

BIS Data

Average credit 5 years before Crisis 11% GDP

Average after: 3.7% GDP
Mainstream ignores private debt

- Lending as a “pure redistribution”; bank as intermediary

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<tr>
<td></td>
<td>Reserves</td>
<td>Saver</td>
<td>Investor</td>
</tr>
<tr>
<td>Lending</td>
<td>From</td>
<td>To</td>
<td></td>
</tr>
<tr>
<td>Paying interest</td>
<td>To</td>
<td>From</td>
<td></td>
</tr>
<tr>
<td>Repaying</td>
<td>From</td>
<td>To</td>
<td></td>
</tr>
<tr>
<td>Bank Fee for arranging loan</td>
<td>From</td>
<td>To</td>
<td></td>
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</tbody>
</table>

- Lending as money creation; bank as originator of loans

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</table>

- An essential difference...
Loanable Funds vs Endogenous Money

- Modelling this in Minsky:

Controls to vary speed of lending and repayment
Loanable Funds vs Endogenous Money

- Change banks from “Intermediators” to “Originators”
Loanable Funds vs Endogenous Money

• 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 \textit{real} economic growth exceeds the sum of population growth and growth in labor productivity;
  – The wages share of output will rise if \textit{money wage demands} exceed the \textit{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 \textit{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

\[ \pi_s = 1 - \omega(t) - r(t) \cdot d(t); \pi_r = \frac{\pi_s}{\lambda} \]

Inflation-adjusted nominal interest rate

1st order time lag determines inflation

\[ \frac{1}{d}\frac{d}{dt} = \left( \frac{f_{n\ell}(\tau_{t})}{\nu} \delta_{Kr} \right) - (\alpha + \beta) \]

Inflation affects wages share

Inflation affects debt growth

Lagged interest rate reaction to inflation
Simple complex systems model...

- The same model in **Minsky**:
Modelling role of energy in production

- Neoclassical: Cobb-Douglass 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 \( \alpha = 0 \)), 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

\[
\text{Work}_{\text{ByLabor}} = \text{Labor} \cdot \frac{\text{Exergy}_{\text{Person}}}{\text{EmbodiedEnergy}_{\text{Person}}} \cdot \text{EmbodiedEnergy}_{\text{Person}} \\
\text{Work}_{\text{ByMachines}} = \text{Machines} \cdot \frac{\text{Exergy}_{\text{Machine}}}{\text{EmbodiedEnergy}_{\text{Machine}}} \cdot \text{EmbodiedEnergy}_{\text{Machine}} \\
Y_R = W_L^\alpha \cdot W_K^{1-\alpha} = (L \cdot E_L \cdot e_l)^\alpha \cdot (K \cdot E_K \cdot e_K)^{1-\alpha} = L^\alpha \cdot K^{1-\alpha} \quad \text{Solow Residual}
\]

- 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