Energy, Finance, and Macroeconomics

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Dynamic Stochastic General Equilibrium

- Overwhelmingly dominant school in macroeconomics.
- Seeks to explain the aggregate economy using theories based on strong microeconomic foundations.
- 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 and only affects price levels.
- Largely ignores the role of (irreducible) uncertainty.

Hardcore (freshwater) DSGE

- The strand of DSGE economists affiliated with RBC theory made the following predictions after 2008:
  1. Increases government borrowing would lead to higher interest rates on government debt because of "crowding out".
  2. Increases in the money supply would lead to inflation.
  3. Fiscal stimulus has zero effect in an ideal world and negative effect in practice (because of decreased confidence).

Wrong prediction number 1

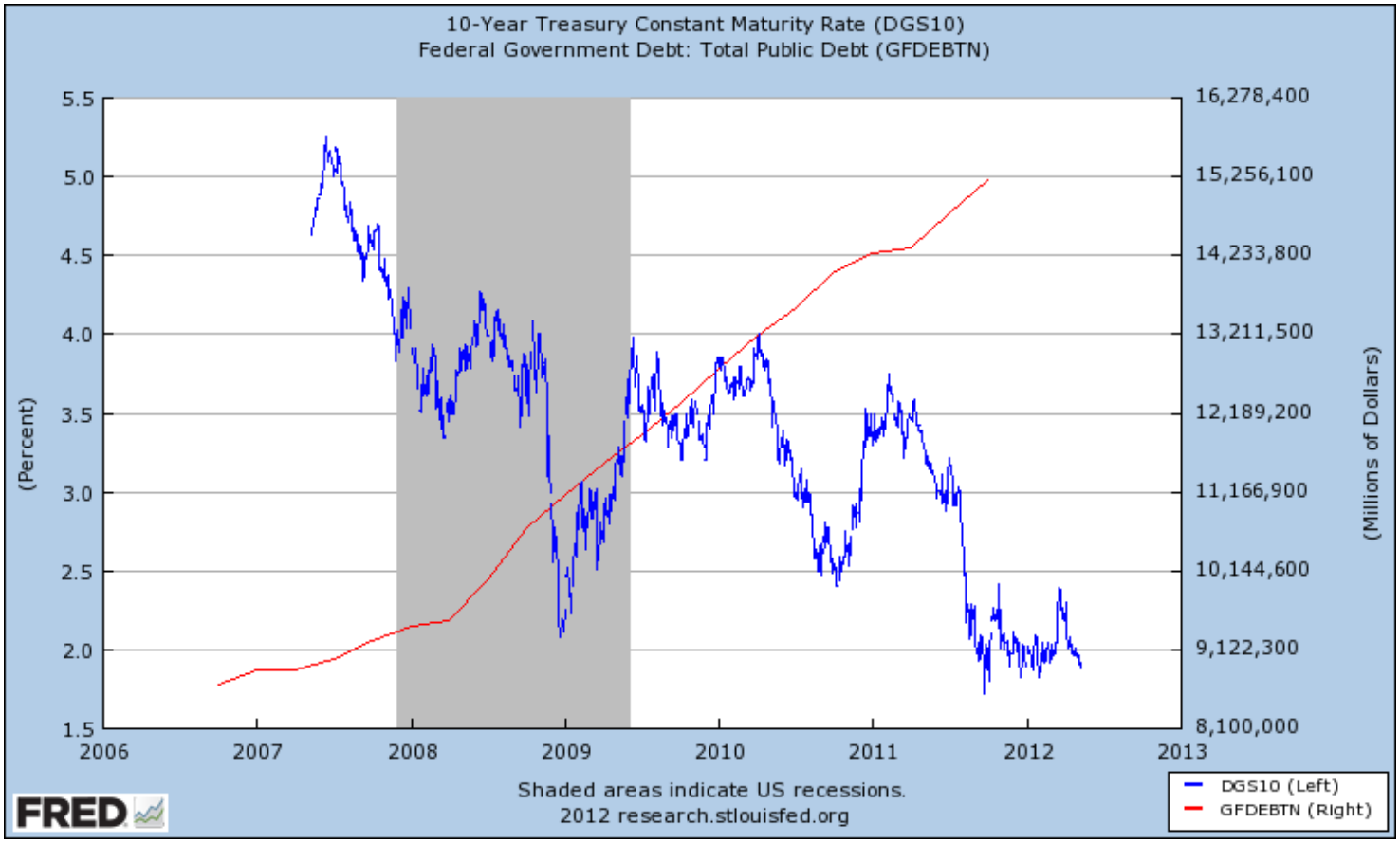


Figure: Government borrowing and interest rates.

Wrong prediction number 2

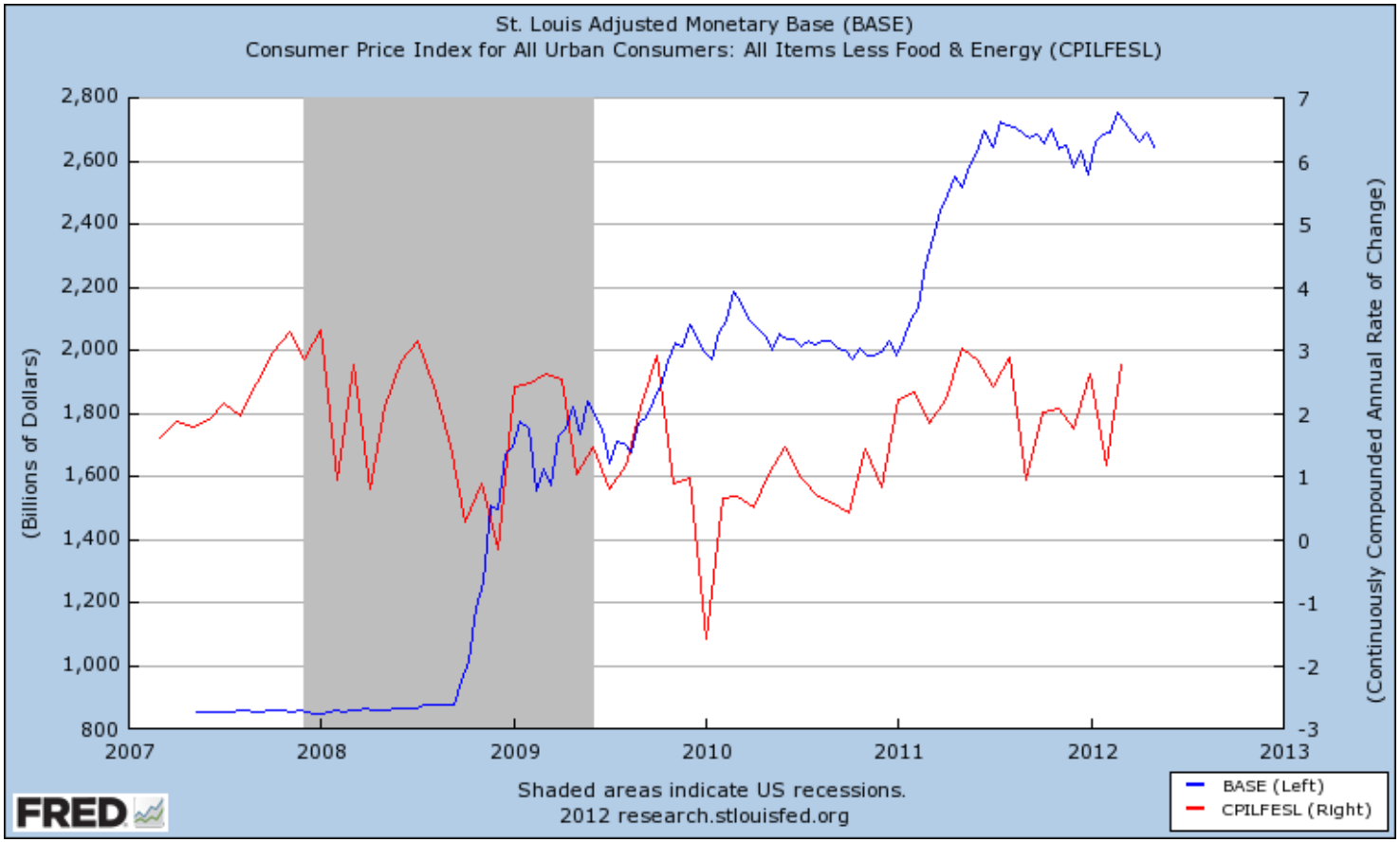


Figure: Monetary base and inflation.

Wrong prediction number 3

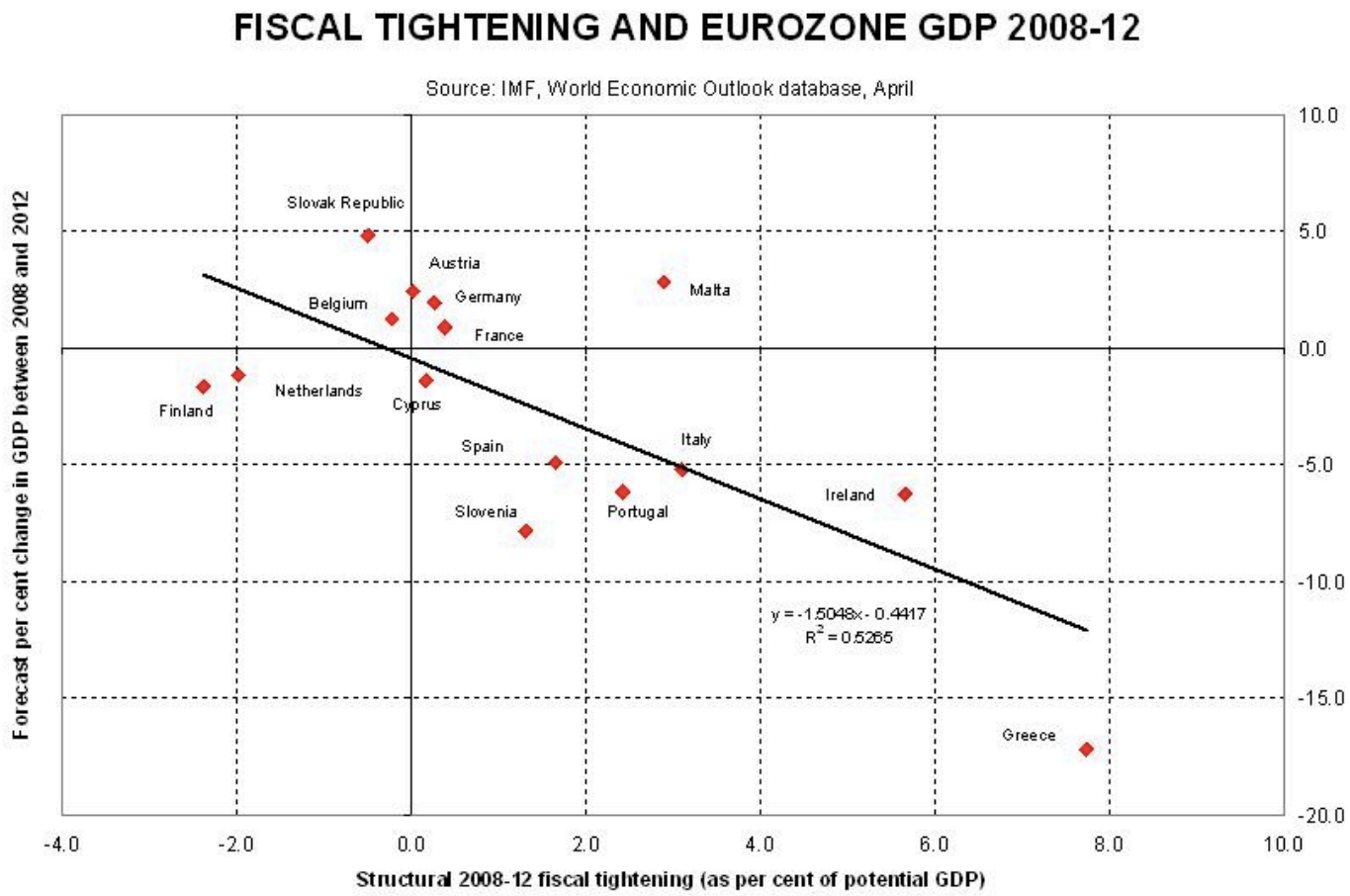


Figure: Fiscal tightening and GDP.

Soft core (saltwater) DSGE

- The strand of DSGE economists affiliated with New Keynesian theory got all these predictions right.
- They did so by augmented DSGE with 'imperfections' (wage stickiness, asymmetric information, imperfect competition, etc).
- Still DSGE at core - analogous to adding epicycles to Ptolemaic planetary system.
- For example: "Ignoring the foreign component, or looking at the world as a whole, the overall level of debt makes no difference to aggregate net worth – one person's liability is another person's asset." (Paul Krugman and Gauti B. Eggertsson, 2010, pp. 2-3)

Then we can safely ignore this...

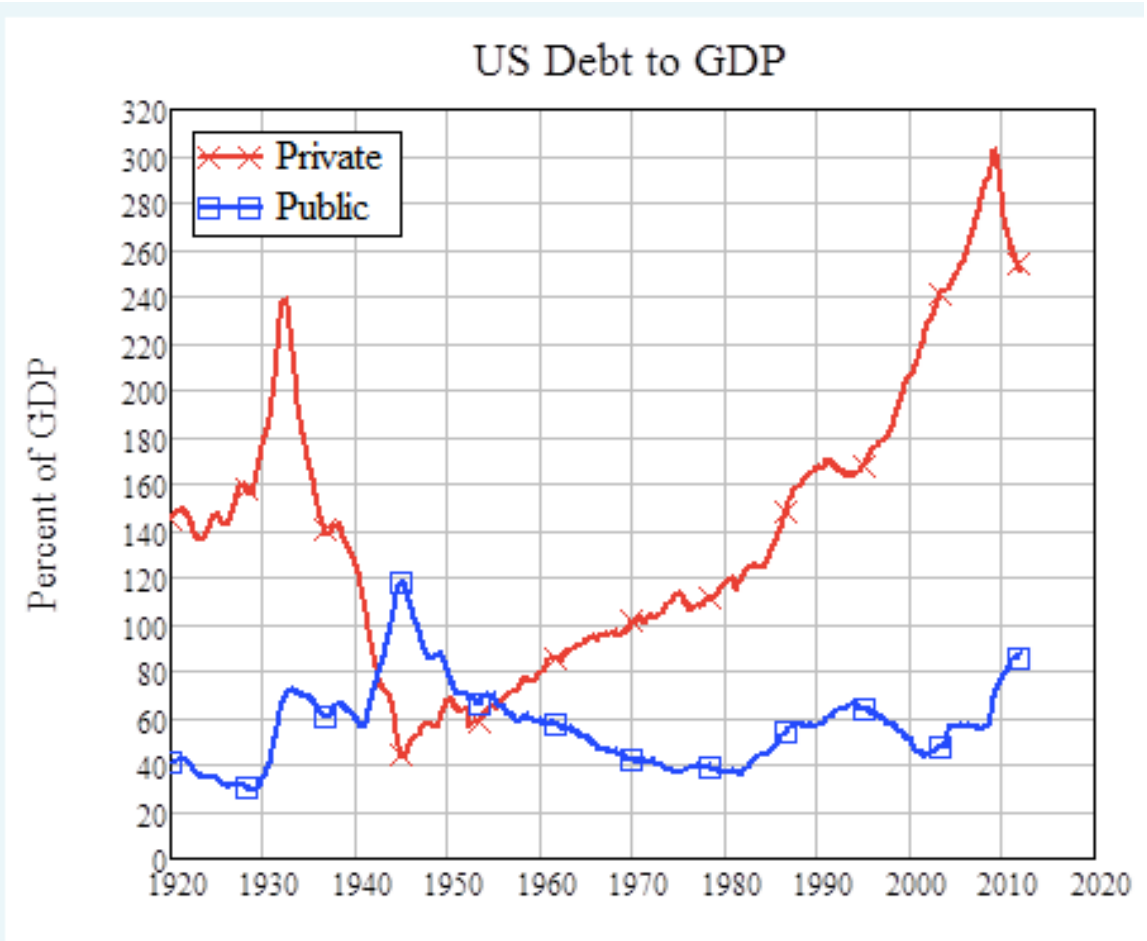


Figure: Private and public debt ratios.

Really?

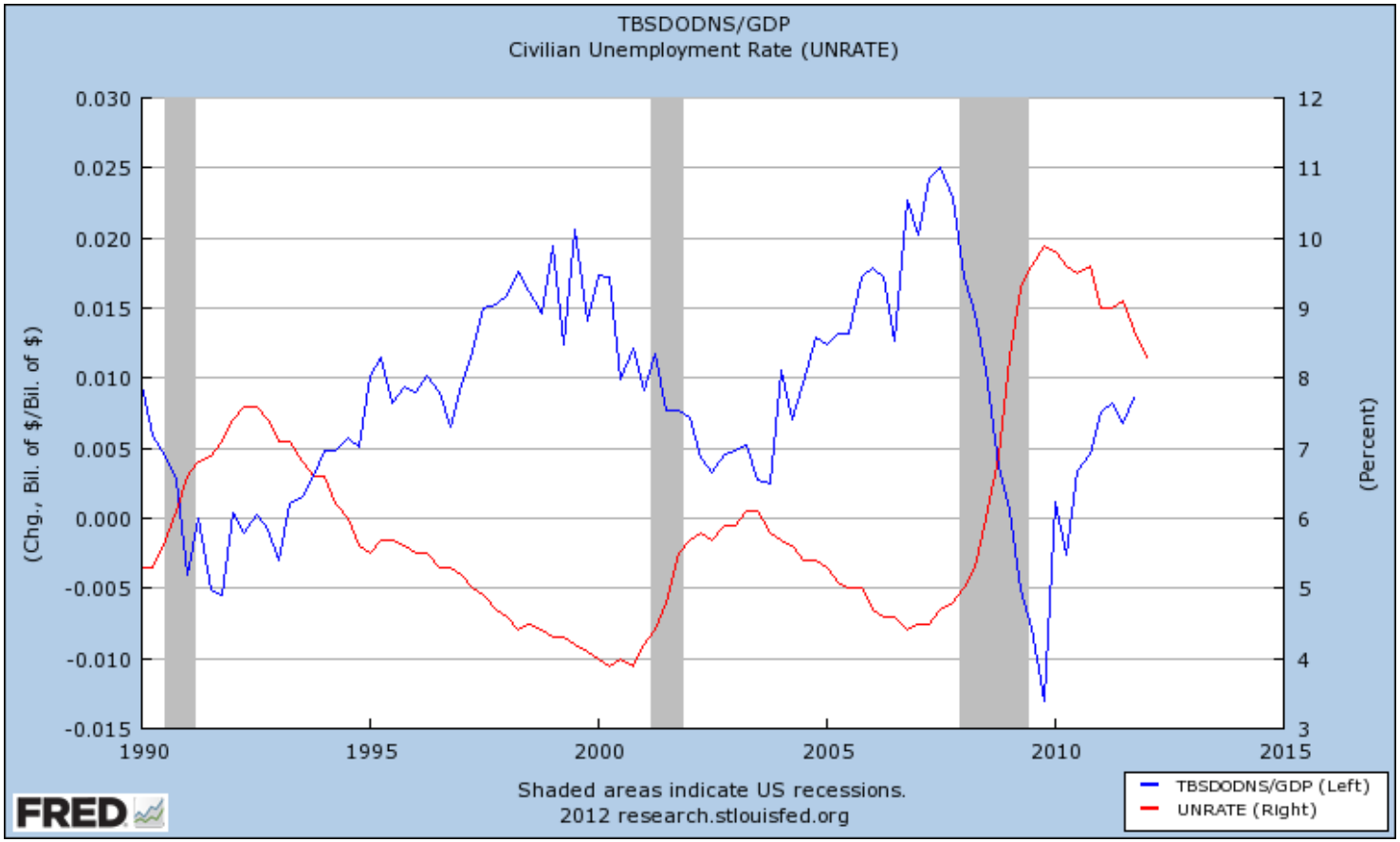


Figure: Change in debt and unemployment.

Minsky's alternative interpretation of Keynes

- 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

- 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.
- 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".

Much better economics: SFC models

- Stock-flow consistent models emerged in the last decade as a common language for many heterodox schools of thought in economics.
- Consider both real and monetary factors from the start
- Specify the balance sheet and transactions between sectors
- Accommodate a number of behavioural assumptions in a way that is consistent with the underlying accounting structure.
- Reject silly (and mathematically unsound!) hypotheses such as the RARE individual (representative agent with rational expectations).
- See Godley and Lavoie (2007) for the full framework.

An example of a (fairly general) Godley table

Balance Sheet	Households	Firms current	Firms capital	Banks	Central Bank	Gov	Sum
Capital			$+K$				+K
Cash	$+H_h$		$+H_f$	$+H_b$	$-H$		0
Advances				$-A$	$+A$		0
Deposits	$+M_h$		$+M_f$	$-M$			0
Loans			$-L$	$+L$			0
Bills	$+B_h$		$+B_f$	$+B_b$	$+B_c$	$-B$	0
Equities	$+p_f E_f + p_b E_b$		$-p_f E_f$	$-p_b E_b$			0
Sum (net worth)	V_h		V_f	V_b	0	V_g	K
Transactions							
Consumption	$-C$	$+C$					0
Gov spending		$+G$				$-G$	0
Investment		$+I$	$-I$				0
memo [GDP]		[Y]					
Wages	$+W$	$-W$					0
Taxes	$-T_h$	$-T_f$		$-T_b$		$+T$	0
Interest on deposits	$+r_M M_h$	$+r_M M_f$		$-r_M M$			0
Interest on loans		$-r_L L$		$+r_L L - r_A A$	$+r_A A$		0
Interest on bills	$+r_B B_h$	$+r_B B_f$		$+r_B B_b$	$+r_B B_c$	$-r_B B$	0
Profits	$+F_{fd} + F_b$	$-F_f$	$+F_{fu}$	$-F_b$	$-F_c$	$+F_c$	0
Financial Balances	S_h	0	S_f	S_b	0	S_g	0
Flow of Funds							
Cash	$-\dot{H}_h$		$-\dot{H}_f$	$-\dot{H}_b$	$+\dot{H}$		0
Advances				$+\dot{A}$	$-\dot{A}$		0
Deposits	$-\dot{M}_h$		$-\dot{M}_f$	$+\dot{M}$			0
Loans			$+\dot{L}$	$-\dot{L}$			0
Bills	$-\dot{B}_h$		$-\dot{B}_f$	$-\dot{B}_b$	$-\dot{B}_c$	$+\dot{B}$	0
Equities	$-p_f \dot{E}_f - p_b \dot{E}_b$		$+p_f \dot{E}_f$	$+p_b \dot{E}_b$			0
Column sum	0	0	0	0	0	0	0

Godley table for monetary Keen model

Balance Sheet	Households	Firms current	Firms capital	Banks	Sum
Capital goods			$+K$		$+K$
Deposits	$+M_h$		$+M_f$	$-M$	0
Loans			$-L$	$+L$	0
Sum (net worth)	V_h		V_f	V_b	$+K$
Transactions					
Consumption	$-C$	$+C$			0
Investment		$+I$	$-I$		0
Accounting memo [GDP]		[Y]			
Wages	$+W$	$-W$			0
Interest on M	$+r_M M_h$	$+r_M M_f$		$-r_M M$	0
Interest on L		$-r_L L$		$+r_L L$	0
Profits		$-F_f$	$+F_{fu}$		0
Financial Balances	S_h	0	S_f	S_b	0
Flow of Funds					
Deposits	$-\dot{M}_h$		$-\dot{M}_f$	$+\dot{M}$	0
Loans			$+\dot{L}$	$-\dot{L}$	0
Column sum	0	0	0	0	0

Accounting relations for monetary Keen model

- From the first, second and third columns of the transactions and flow of funds matrices we obtain that

$$W + r_M M_h - C = S_h = \dot{M}_h, \tag{1}$$

$$C - W + r_M M_f - r_L L = F_{fu} - I = \dot{M}_f - \dot{L} \tag{2}$$

$$r_L L - r_M M = S_b = \dot{L} - \dot{M}. \tag{3}$$

- An example of firm behaviour satisfying (1)–(3) is

$$\dot{L} = I - R \tag{4}$$

$$\dot{M}_f = I - R + C - W + r_M M_f - r_L L \tag{5}$$

for chosen levels of investment I and repayment R.

Special case: Keen (1995)

- Let $D = L - M_f$ and assume that $p = p_0$, $r_M = r_F = r$.
- Supposing further that $\Phi = \Phi(\lambda)$ and $I = \kappa(\pi)Y$, where $\pi = 1 - \omega - rd$, leads to

$$\begin{aligned}
\dot{\omega} &= \omega\left[\Phi(\lambda) - \alpha\right] \\
\dot{\lambda} &= \lambda\left[\frac{\kappa(1-\omega-rd)}{\nu} - \alpha - \beta - \delta\right] \qquad (6) \\
\dot{d} &= d\left[r - \frac{\kappa(1-\omega-rd)}{\nu} + \delta\right] + \kappa(1-\omega-rd) - (1-\omega)
\end{aligned}$$

Equilibria

- The system (6) has a good equilibrium at

$$\overline{\omega} = 1 - \overline{\pi} - r\frac{\nu(\alpha+\beta+\delta)-\overline{\pi}}{\alpha+\beta}$$

$$\overline{\lambda} = \Phi^{-1}(\alpha)$$

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

with

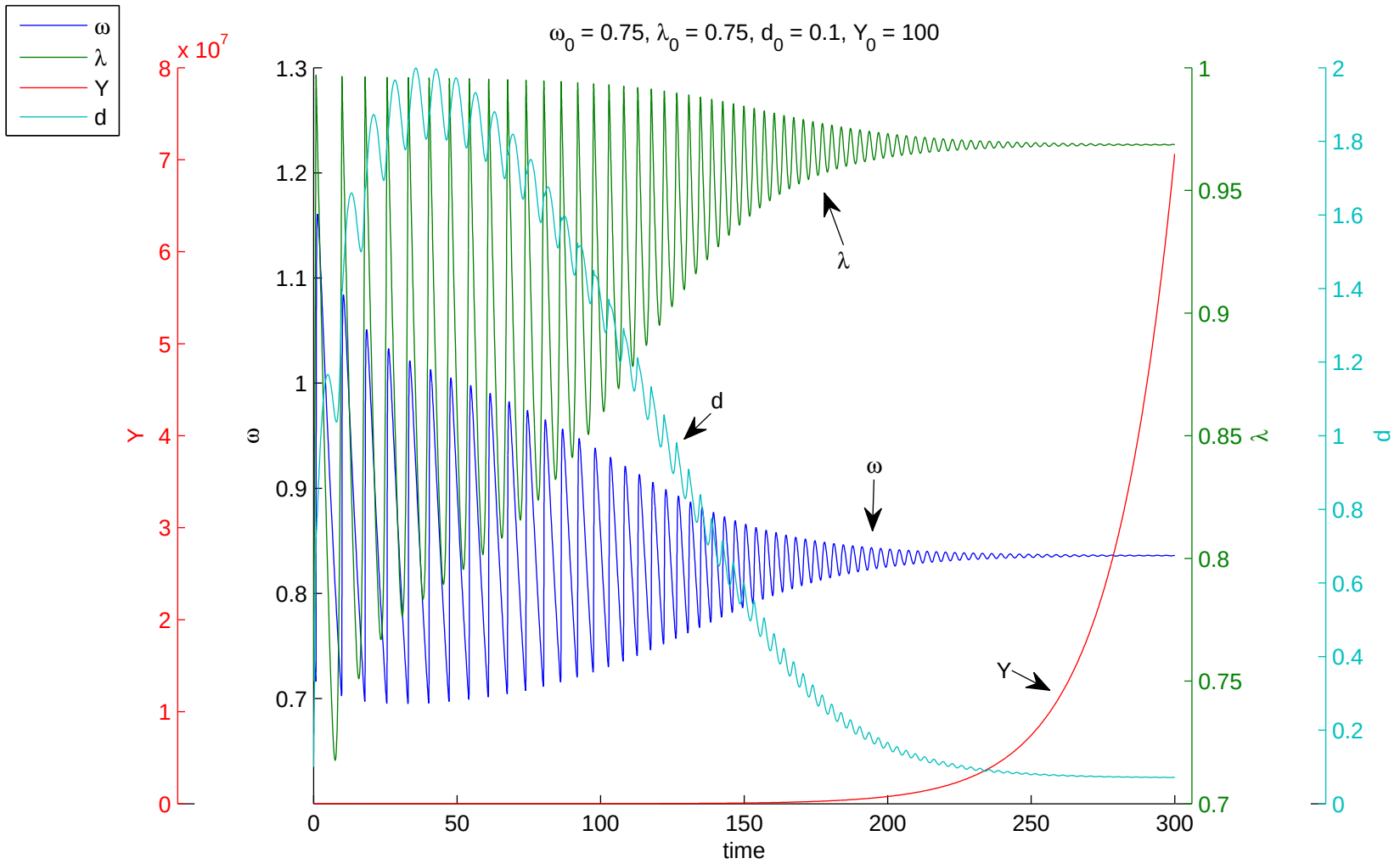
$$\overline{\pi} = \kappa^{-1}(\nu(\alpha+\beta+\delta)),$$

which is stable for a large range of parameters

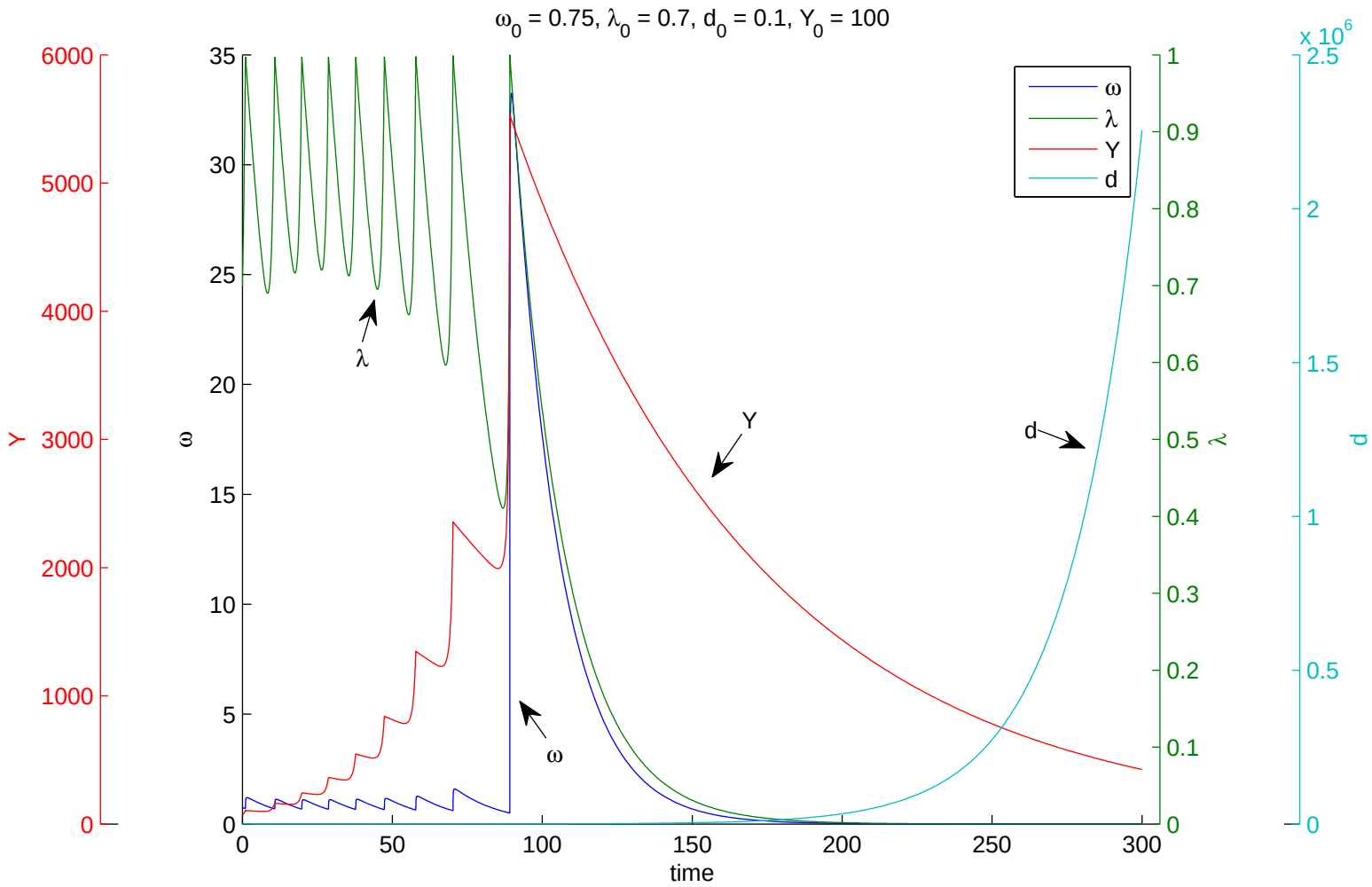
- It also has a bad equilibrium at $(0, 0, +\infty)$, which is stable if

$$\frac{\kappa(-\infty)}{\nu} - \delta < r \tag{7}$$

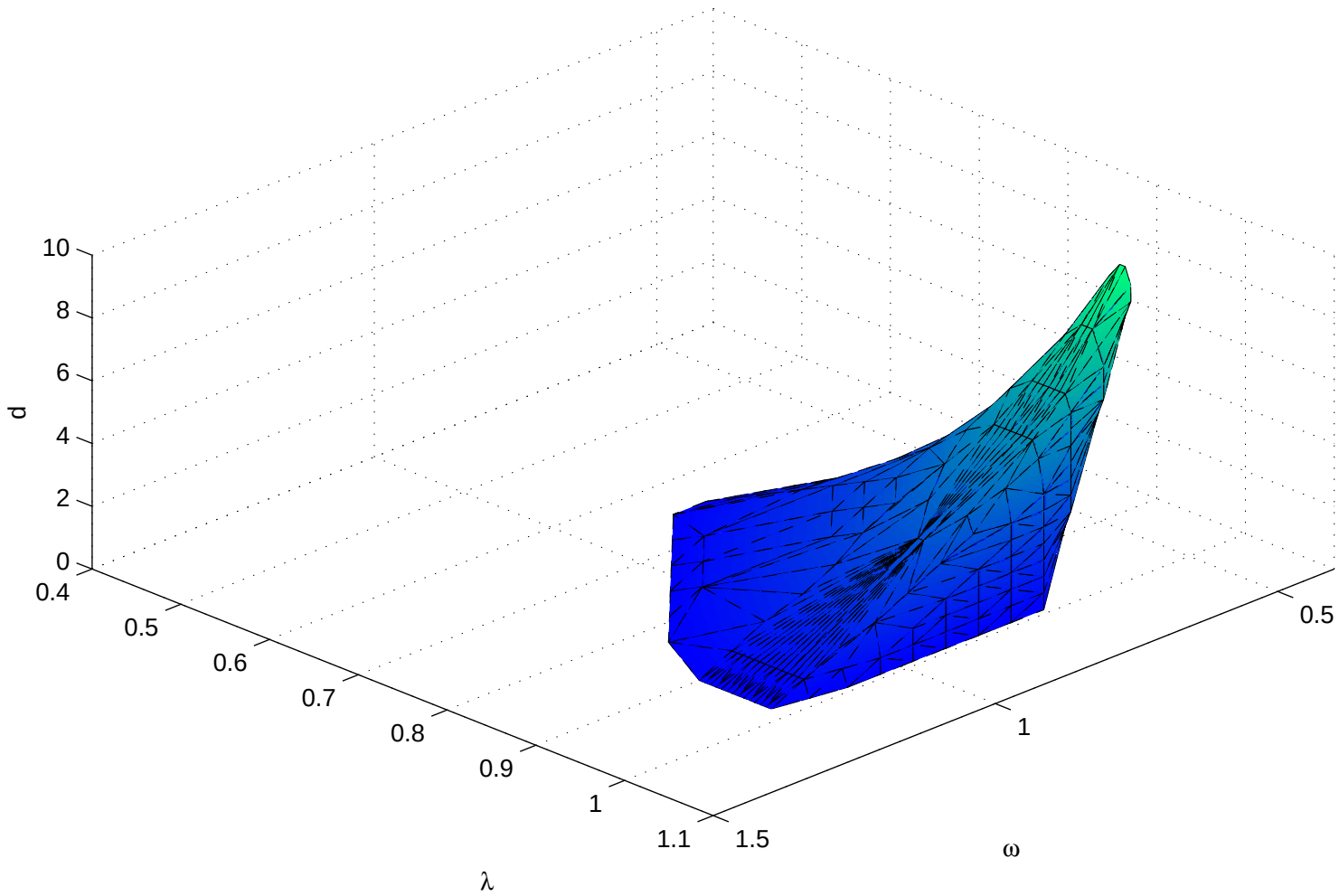
Example 1: convergence to the good equilibrium in a Keen model



Example 2: explosive debt in a Keen model



Basin of convergence for Keen model



Godley table for model with government

Balance Sheet	Households	Firms current	Firms capital	Banks	Gov	Sum
Capital goods			$+K$			$+K$
Deposits	$+M_h$		$+M_f$	$-M$		0
Loans			$-L$	$+L$		0
Bills	$+B$				$-B$	0
Sum (net worth)	V_h		V_f	V_b	V_g	$+K$
Transactions						
Consumption	$-C$	$+C$				0
Gov Spending		$+G$			$-G$	0
Investment		$+I$	$-I$			0
Accounting memo [GDP]		[Y]				
Wages	$+W$	$-W$				0
Taxes		$-T$			$+T$	0
Subsidies		$+G_s$			$-G_s$	0
Interest on M	$+r_M M_h$	$+r_M M_f$		$-r_M M$		0
Interest on L		$-r_L L$		$+r_L L$		0
Interest on Bills	$+r_B B$				$-r_B B$	0
Profits		$-F_f$	$+F_{fu}$			0
Financial Balances	S_h	0	S_f	S_b	S_g	0
Flow of Funds						
Deposits	$-\dot{M}_h$		$-\dot{M}_f$	$+\dot{M}$		0
Loans			$+\dot{L}$	$-\dot{L}$		0
Bills	$-\dot{B}$				$+\dot{B}$	0
Column sum	0	0	0	0	0	0

Modified Keen model with government

- Following Keen (and echoing Minsky) we model government spending and taxation as

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

and add government subsidies to firms as

$$\dot{G}_s = \Gamma_s(\lambda) G_s$$

- Defining $g = G/Y$, $g_s = G_s/Y$ and $\tau = T/Y$, the net profit share is now

$$\pi = 1 - \omega - rd + g_s - \tau,$$

and government debt evolves according to

$$\dot{B} = r_B B + G + G_s - T.$$

Good equilibrium

- The system (**??**) has a good equilibrium at

$$\overline{\omega} = 1 - \overline{\pi} - r\frac{\nu(\alpha+\beta+\delta)-\overline{\pi}}{\alpha+\beta} - \frac{\Theta(\overline{\pi})}{\alpha+\beta}$$

$$\overline{\lambda} = \Phi^{-1}(\alpha)$$

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

$$\overline{g}_s = 0$$

  and this is locally stable for a large range of parameters.
- The other variables then converge exponentially fast to

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

$$\overline{g} = \frac{\Gamma_b(\overline{\lambda})}{\alpha+\beta}$$

$$\overline{\tau} = \frac{\Theta(\overline{\pi})}{\alpha+\beta}$$

Bad equilibria - destabilizing a stable crisis

- Recall that $\pi = 1 - \omega - rd + g_s - \tau$.
- The model has bad equilibria of the form

$$(\omega, \lambda, g_s, \pi) = (0, 0, 0, -\infty)$$
$$(\omega, \lambda, g_s, \pi) = (0, 0, \pm\infty, -\infty)$$

- If $g_s(0) > 0$, then any equilibria with $\pi \to -\infty$ is locally unstable provided $\Gamma_s(0) > r$.
- On the other hand, if $g_s(0) < 0$ (austerity), then these equilibria are all locally stable.

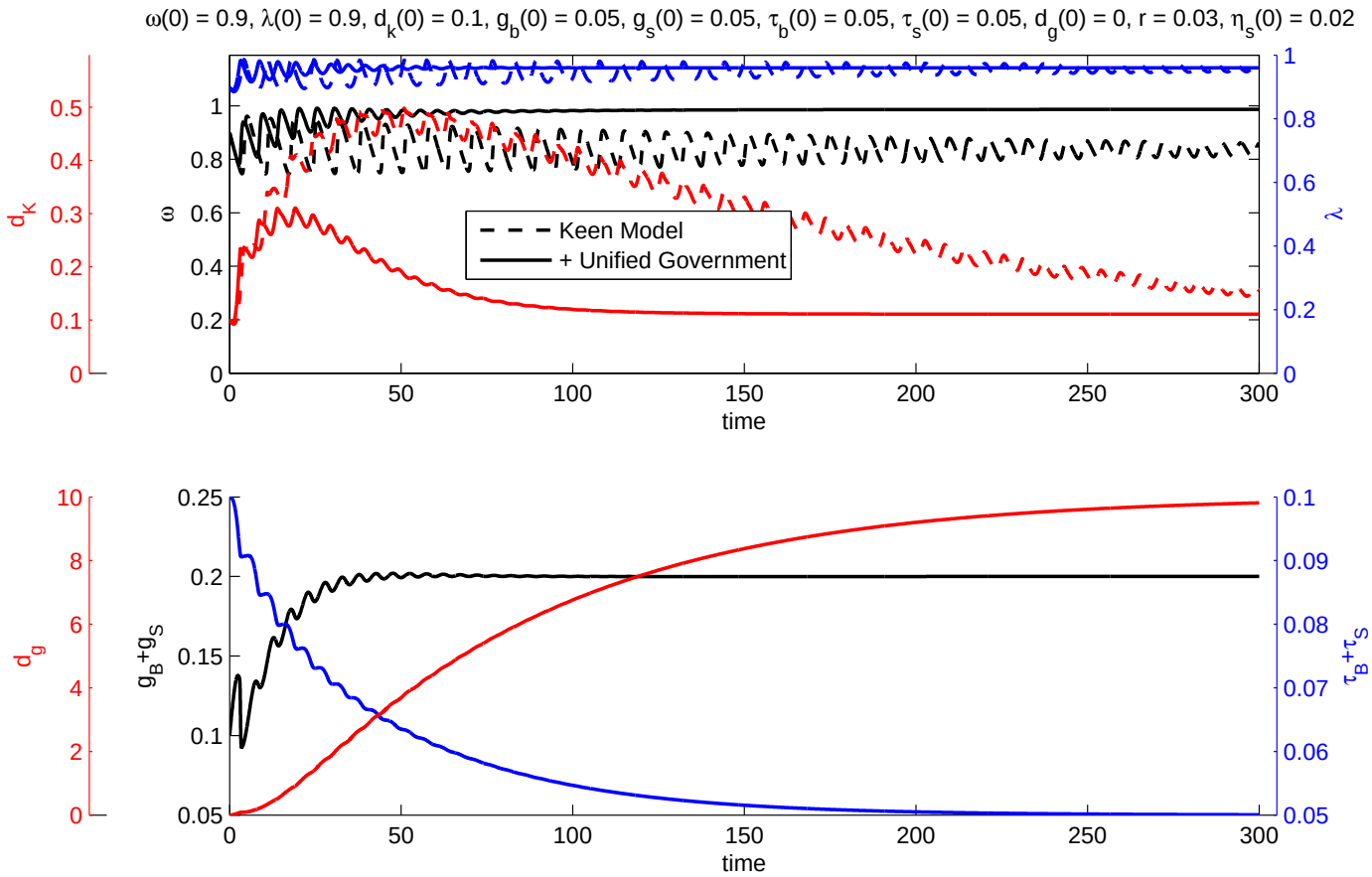
Persistence

Proposition 1: Assume $g_s(0) > 0$, then the model is e^π-UWP provided $\Gamma_s(0) > r$.

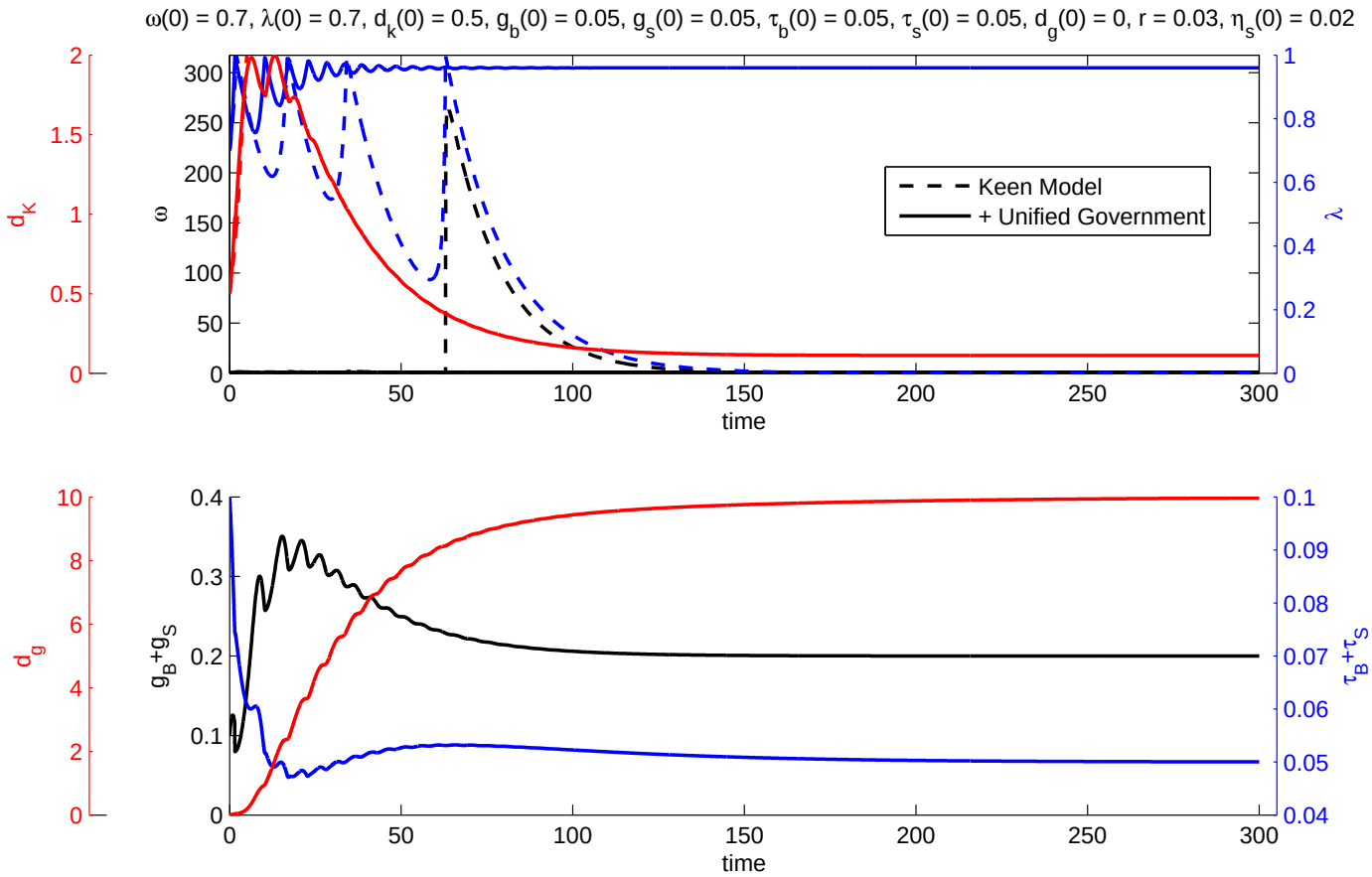
Proposition 2: Assume $g_s(0) > 0$, then the model is λ-UWP if either of the following conditions is satisfied:

1. $\Gamma_s(0) > \max\{r, \alpha + \beta\}$
2. $r < \Gamma_s(0) \leq \alpha + \beta$ and $-r(\kappa(x) - x) + (1 - x)\mu(x) + \Gamma(0) - \Theta(x) > 0$ for $\mu(x) \in [\Gamma_s(0), \alpha + \beta]$.

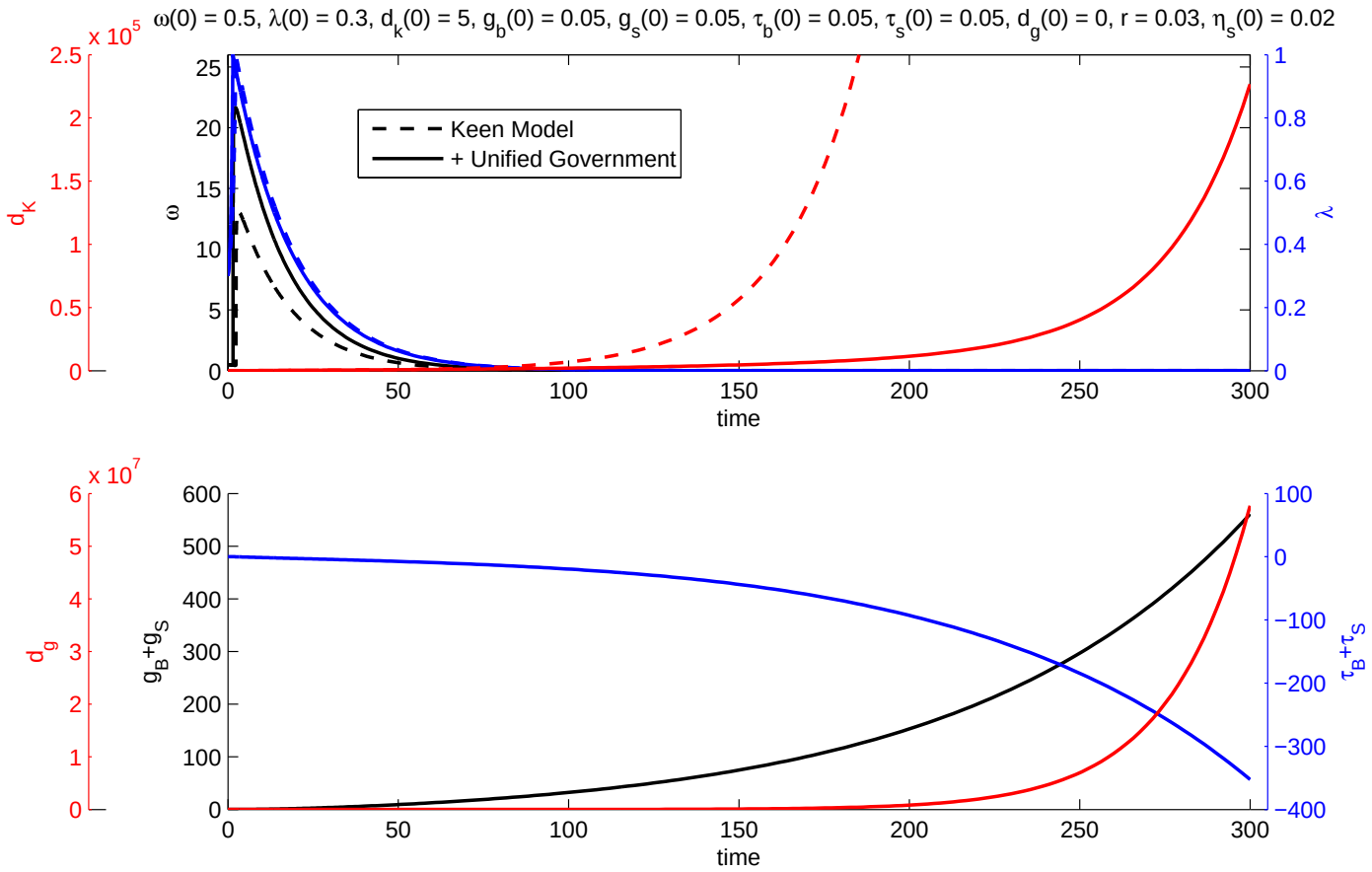
Example 3: Good initial conditions



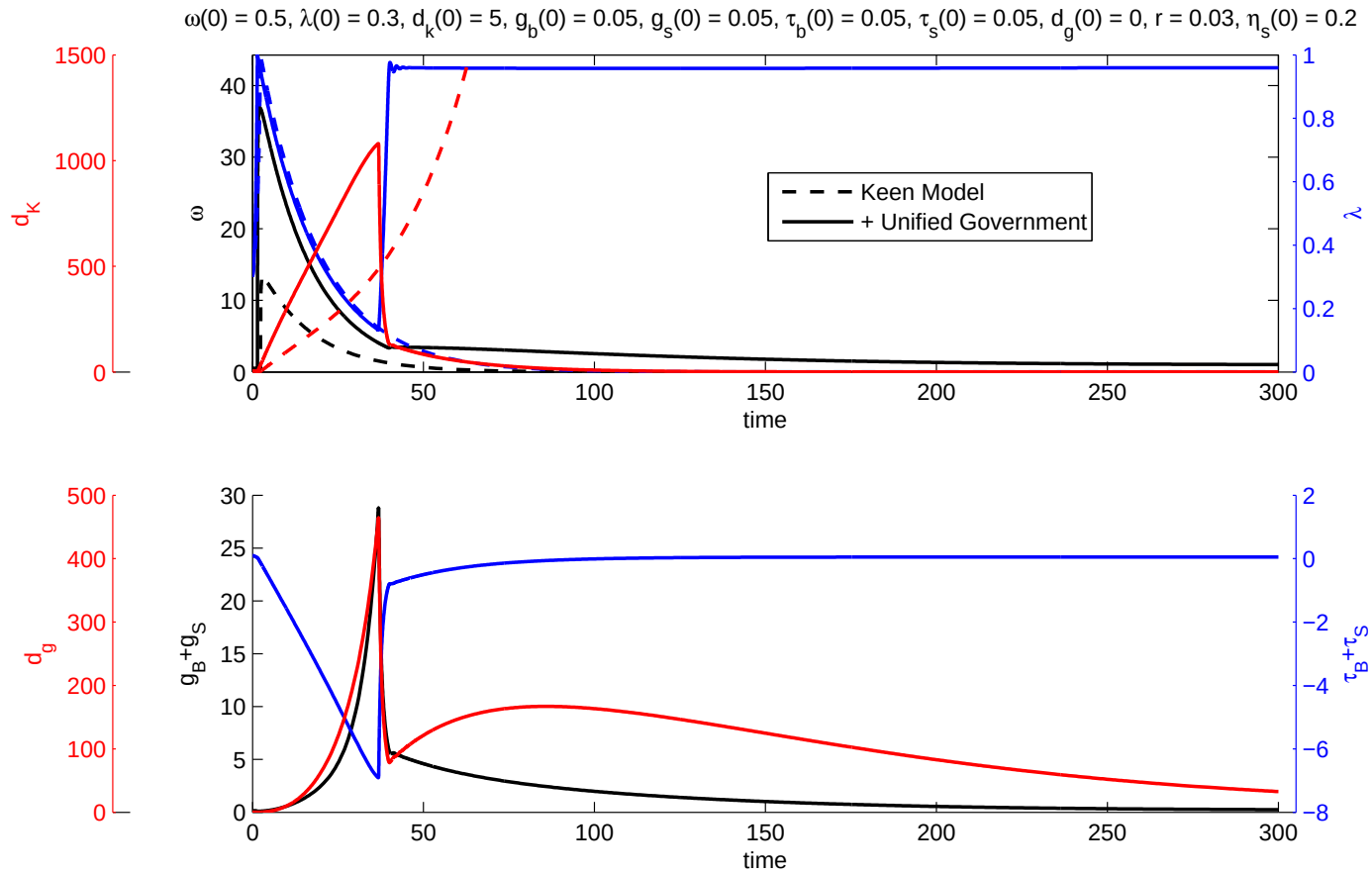
Example 4: Bad initial conditions



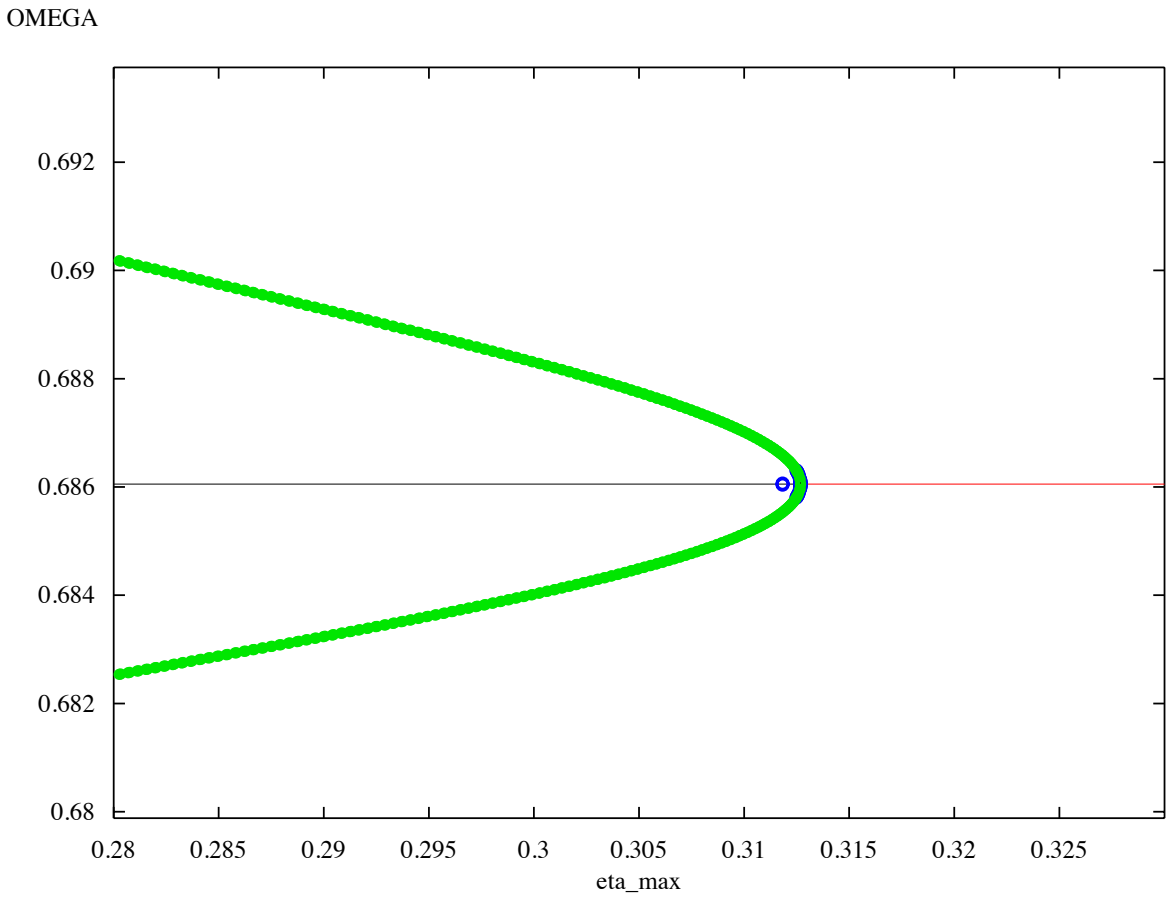
Example 5: Really bad initial conditions with timid government



Example 6: Really bad initial conditions with responsive government



Hopft bifurcation with respect to government spending.



Ponzi financing

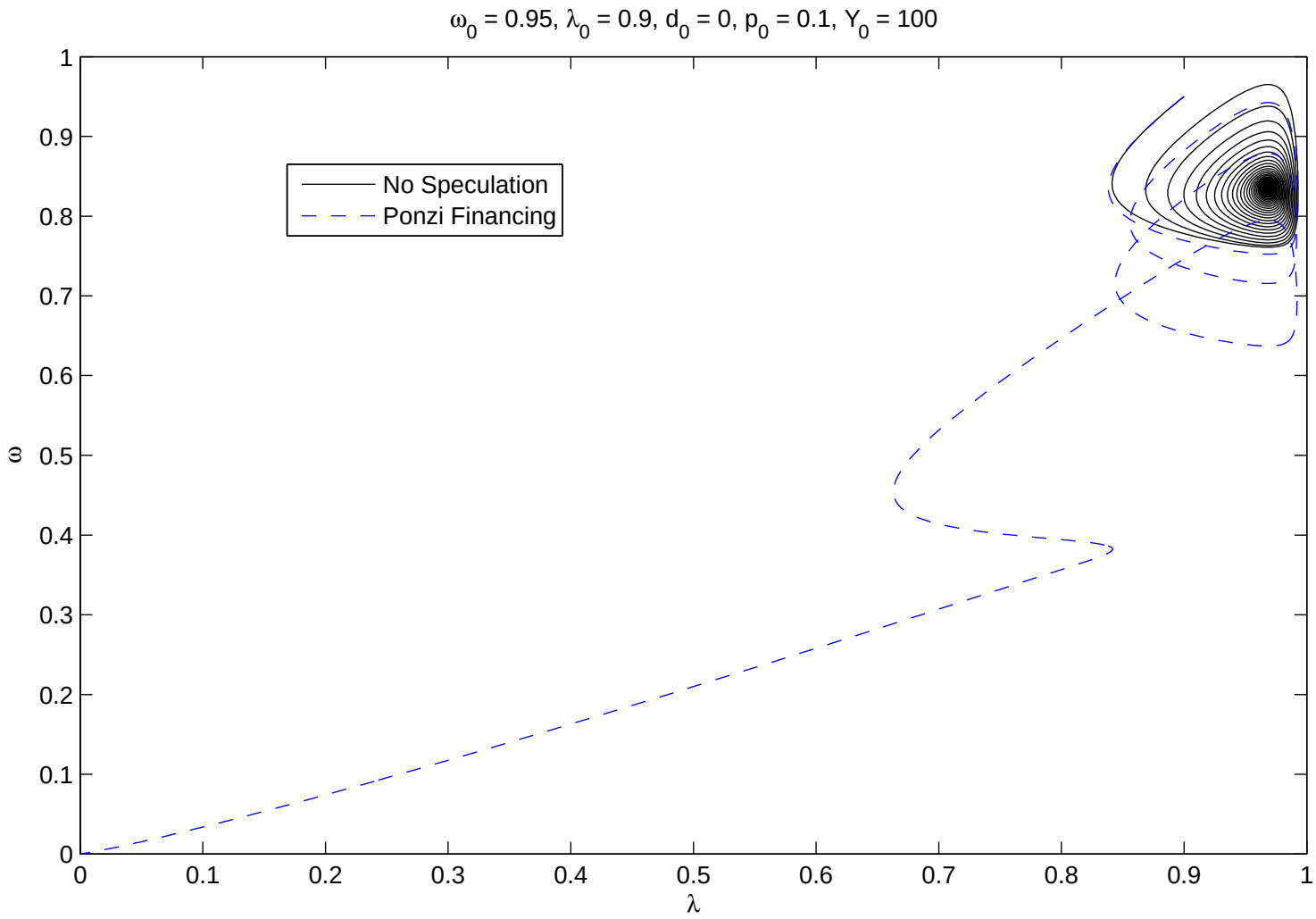
To introduce the destabilizing effect of purely speculative investment, we consider a modified version of the previous model with

$$\dot{D} = \kappa(1-\omega-rd)Y - (1-\omega-rd)Y + P$$
$$\dot{P} = \Psi(g(\omega,d)P$$

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

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

Example 7: effect of Ponzi financing



Stock prices

- Consider a stock price process of the form

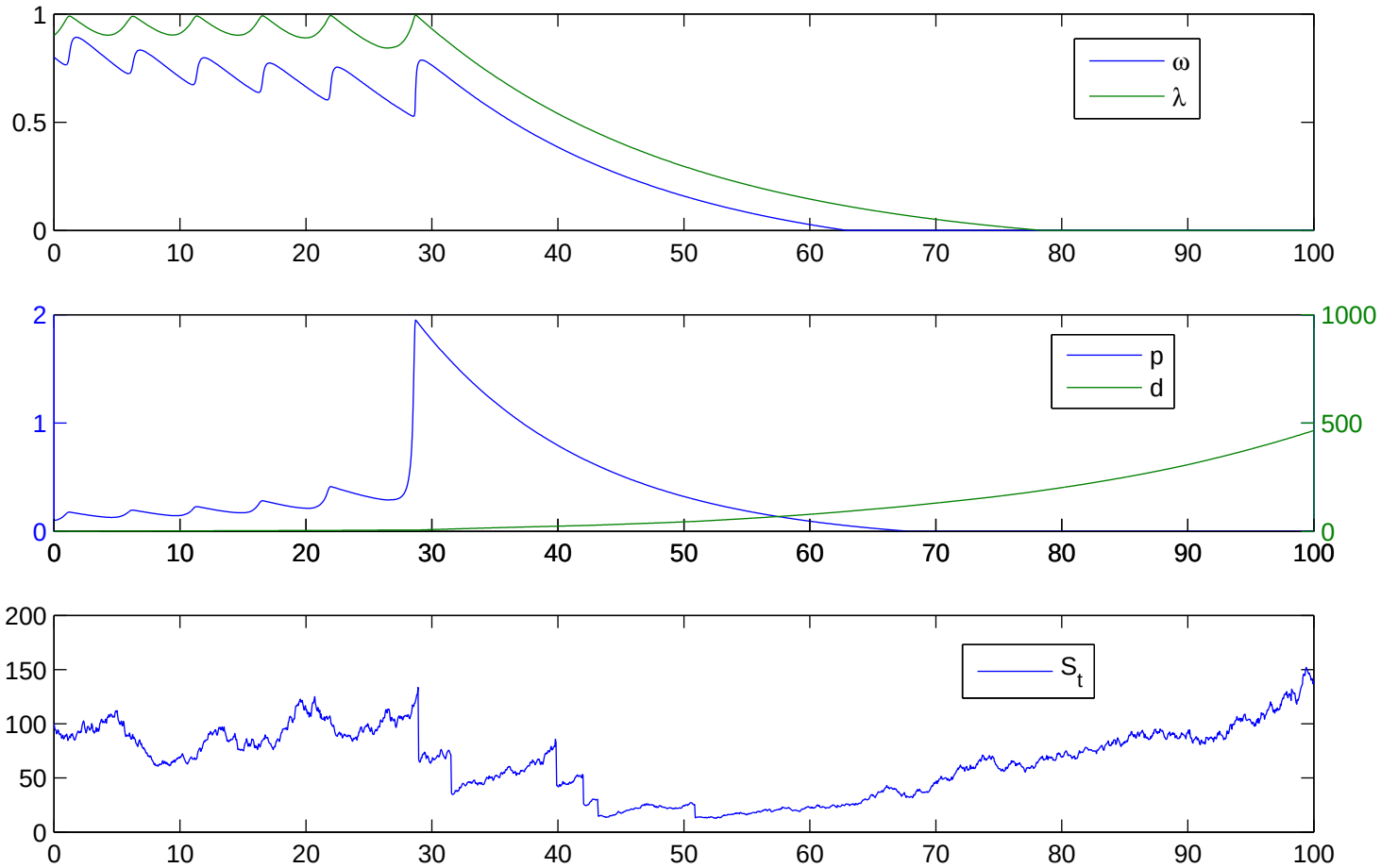
$$\frac{dS_t}{S_t} = r_b dt + \sigma dW_t + \gamma \mu_t dt - \gamma dN^{(\mu_t)}$$

where N_t is a Cox process with stochastic intensity $\mu_t = M(p(t))$.

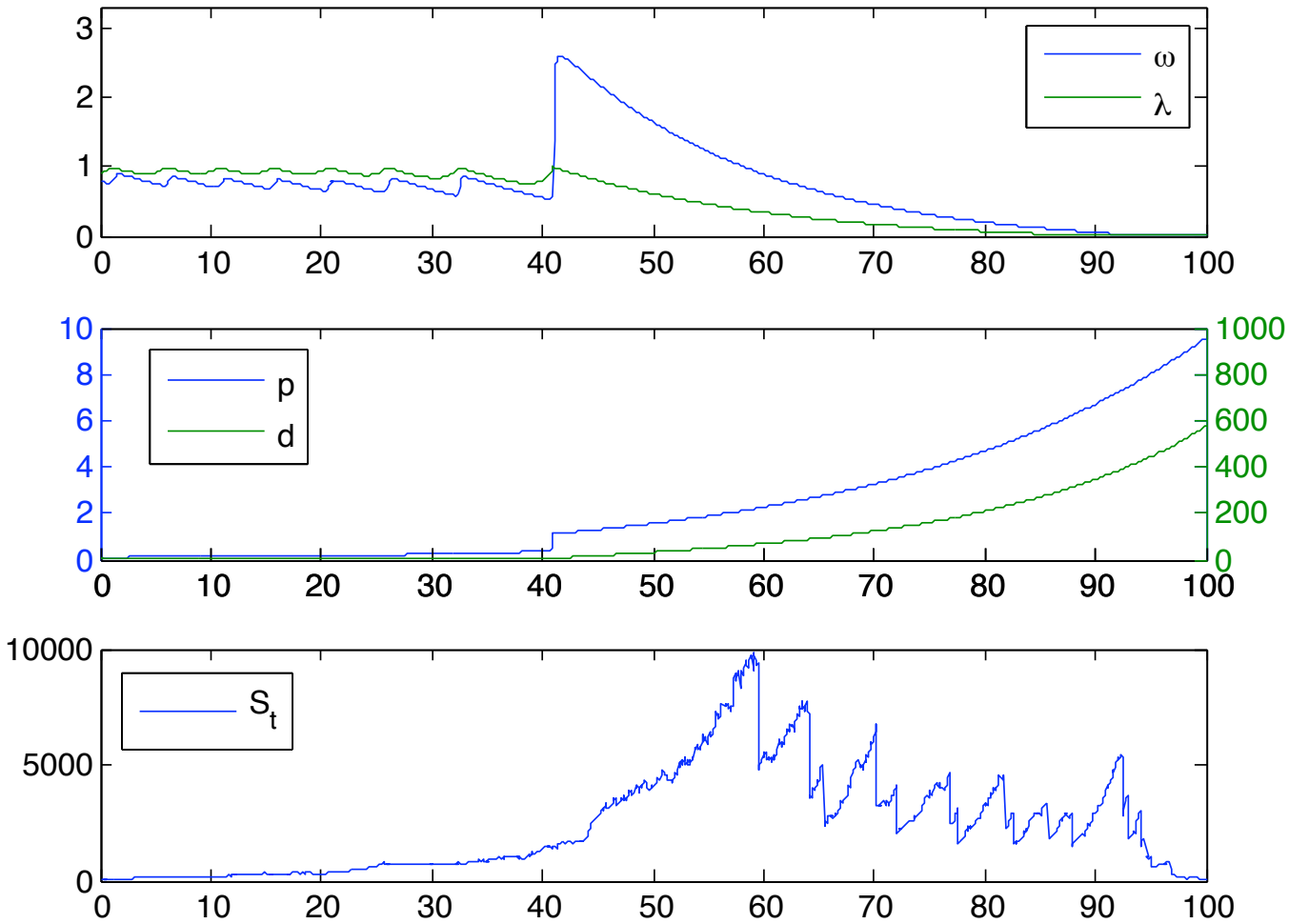
- The interest rate for private debt is modelled as $r_t = r_b + r_p(t)$ where

$$r_p(t) = \rho_1 (S_t + \rho_2)^{\rho_3}$$

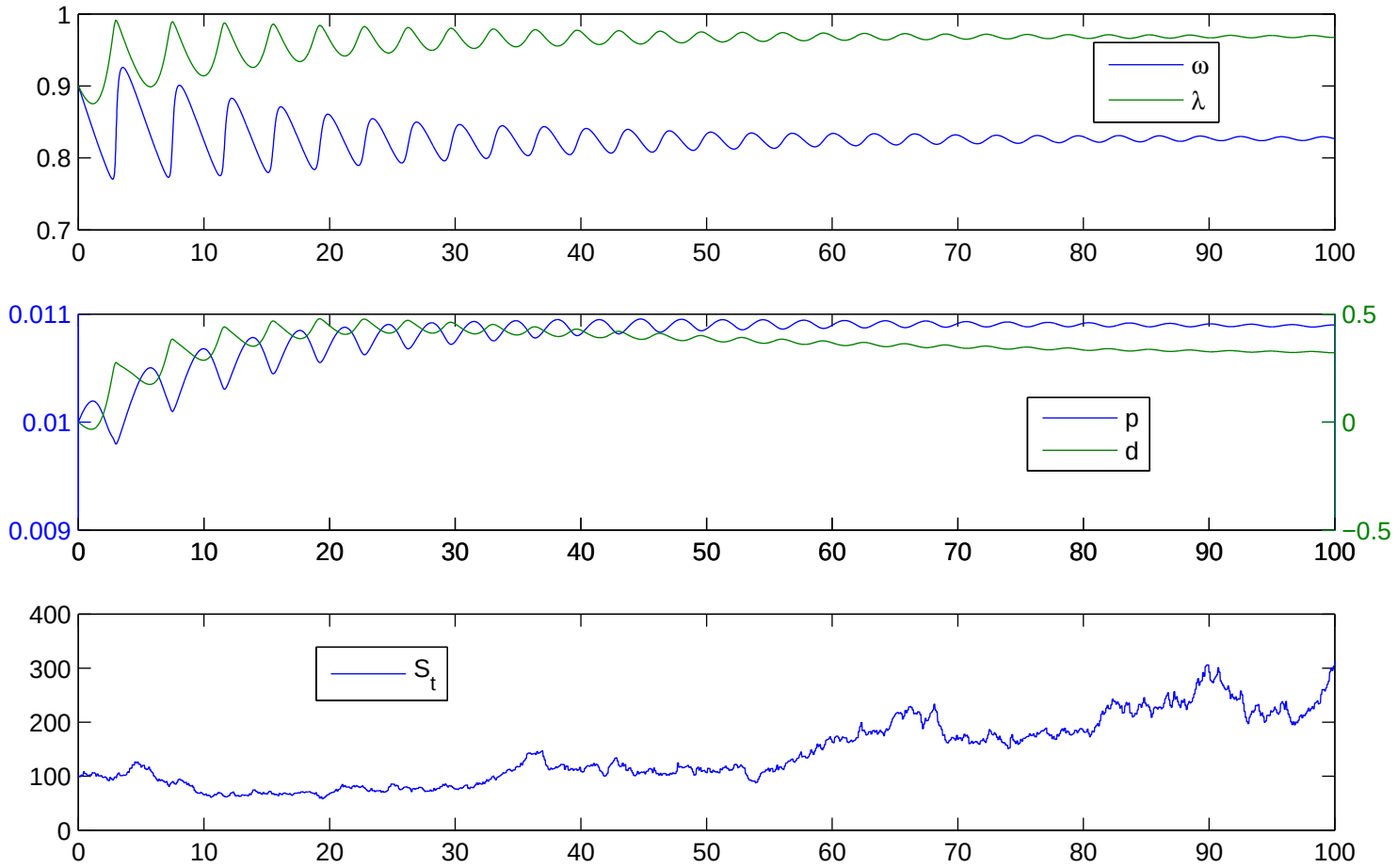
Example 8: stock prices, explosive debt, zero speculation



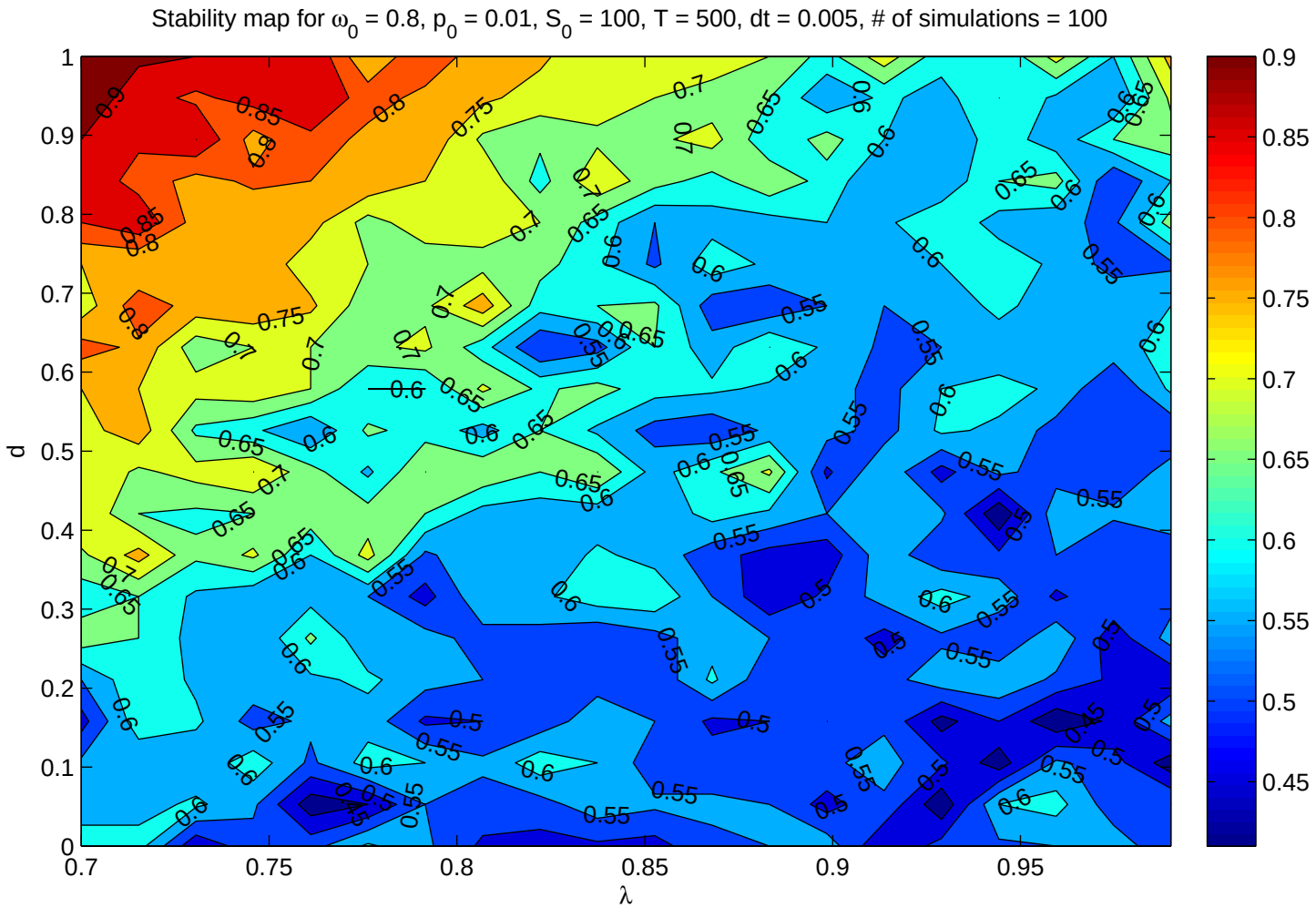
Example 9: stock prices, explosive debt, explosive speculation



Example 10: stock prices, finite debt, finite speculation



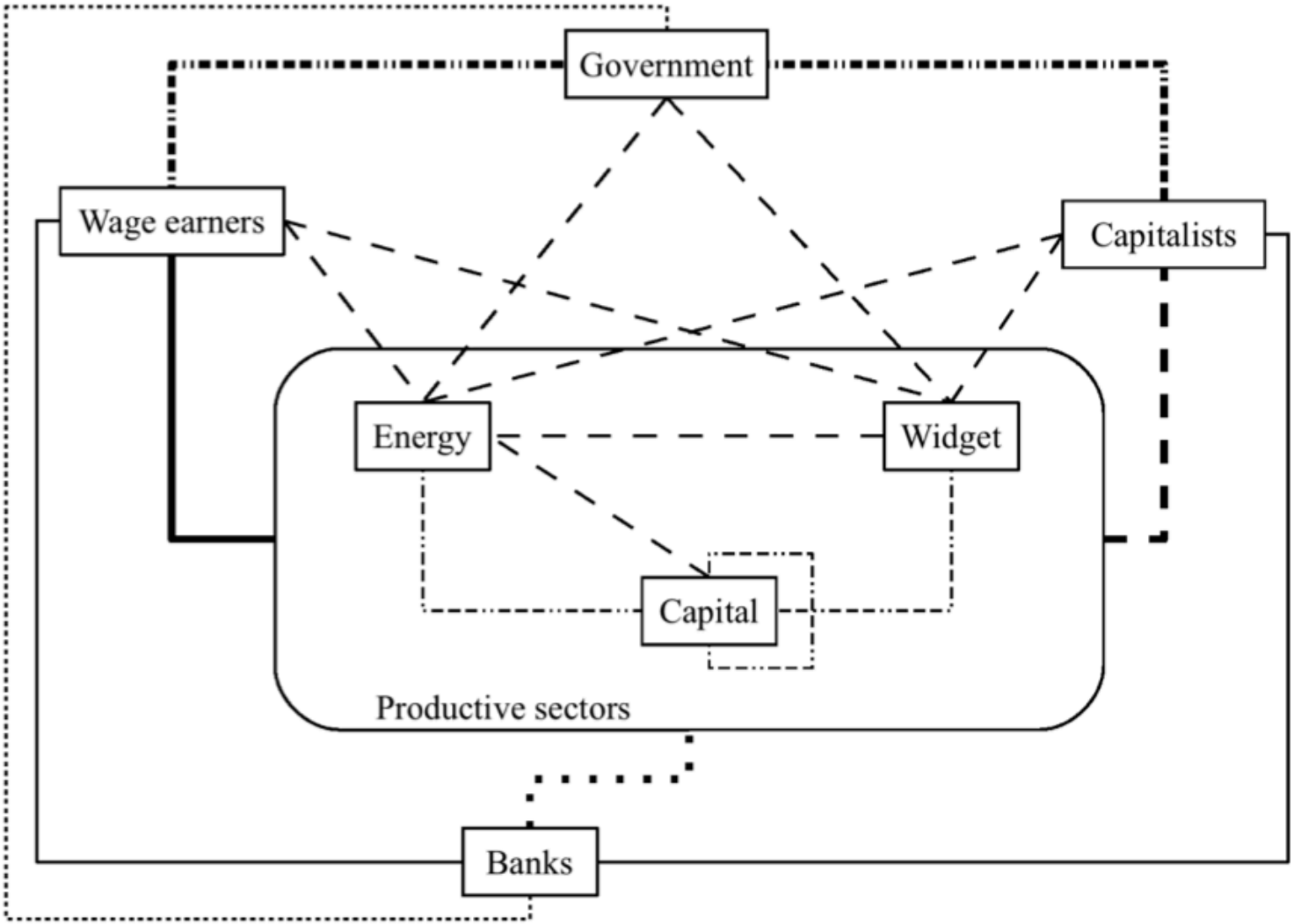
Stability map



A model with the energy sector (Godin 2012)

- Consider 3 productive sectors (widgets, capital goods, energy), 2 household sectors (wage earners and capitalists), a government, and banks.
- All sectors consume energy; wage earners and capitalists consume widgets; all productive sectors by capital goods and pay wages; all firms and banks are owned by capitalists.
- Government collects taxes on households, pays employment benefit, and issues bonds.
- Banks make loans and accept deposits.

Flows in the Godin model



Behavioural assumptions in the Godin model

- Consumption for wage earners and capitalists depend on preferences for energy and widgets and current wealth. Income not consumed is saved in bonds (depending on wealth and interest rate) and the rest in cash.
- Investment depend on current and target capacity utilization.
- Prices are given by a mark-up factor further subdivided into retained and distributed profits.
- Retained profits depend on target leverage and expected unit costs, which in turn determine possible prices.
- Investment in excess of retained profits is financed by loans.
- Banks accept all demand for loans and use government bonds as residual.

Guaranteed Employer of Last Resort: Green Jobs

- Government intervenes by hiring all unemployed workers at a minimum age to work in energy saving projects.
- Unemployment benefit is replaced by wages.
- Energy consumption by government and households changes to

$$C_{g,e} = (1 - \xi_g u) C_{g,e,-1}$$
$$\beta_h = (1 - \xi_h u) \beta_h - 1$$

Results in the Godin model

Figure 8. Private unemployment

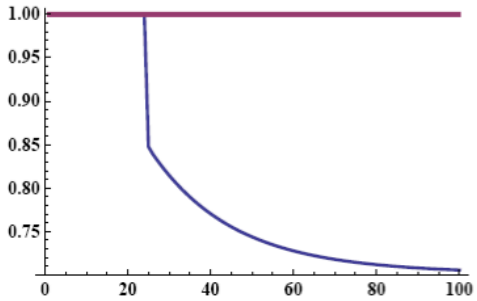


Figure 9. Government budget

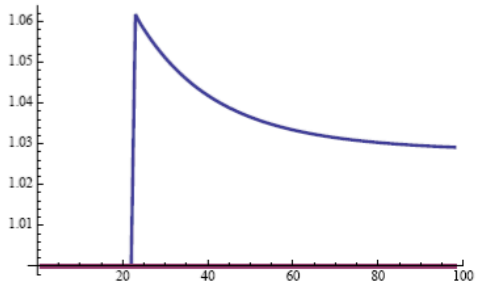


Figure 10. Debt to GDP

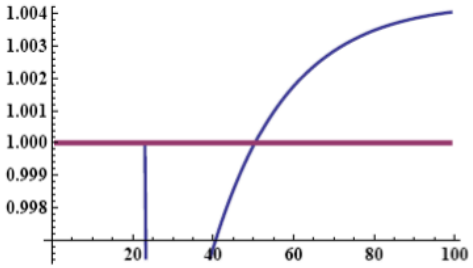


Figure 11. Employment

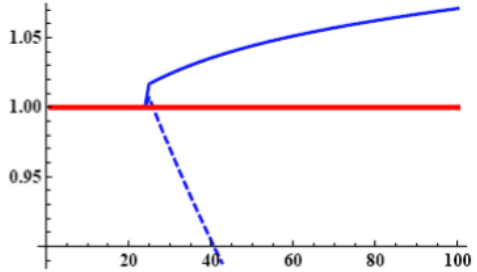


Figure 12. Income

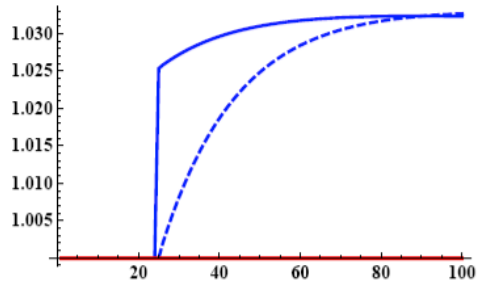
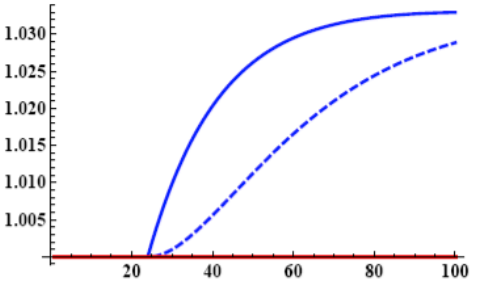


Figure 13. Wealth



Concluding thoughts

- Opportunities abound to add more structure and detail to SFC models with an explicit energy sector, including other types of investment functions, more realistic financial markets, commodities prices, derivatives, etc.
- For example, the effect of inventories in forward curves mentioned by G. Swindle this morning is a prime example of the interaction between real and financial sectors that can be model in a SFC way.
- This innovative way of macroeconomic modelling has just begun and has the potential to be a paradigm shifting development that, together with complementary work on incomplete knowledge, radical uncertainty, network theory, and agent-based models, can redefine the role of mathematics in economic theory.