Introduction to SFC Dynamic Models

Lecture B A Toy Model with State Money and Bills

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Download lectures' material from:

https://github.com/marcoverpas/Six_lectures_on_sfc_models

Schedule

A. Foundations of SFC Models for Economic Research

B. A Toy Model with State Money and Bills

1. **Introduction**
2. **Model Accounting**
3. **Simulations**
4. **Modelling PC in *R***

C. A Toy Model with Bank Money and Fixed Capital

D. Multi-Country SFC Models

E. Ecological and Input-Output SFC Models

F. Empirical SFC Models (using *Bimets*)

1 Introduction

Modelling net financial assets

- SFC models are not just stock-flow consistent. They are stock-flow relevant, meaning that they allow the consideration of a variety of both real and financial assets and liabilities.
- Cash, reserves, deposits, corporate loans, personal loans, advances, shares (equity), bills, bonds, fixed capital, and dwellings are included in the most advanced models.
- The simplest models only include cash, deposits, loans, and/or bills.
- Here, we present and discuss two toy models:
    - Model PC, which only considers cash (state money) and government bills
    - Model BMW, which only includes deposits (bank money) and loans, in addition to fixed capital
- While these models are highly abstract and simplified, the underlying logic is the same as that characterising more advanced models.

Box 1 Steps for developing a SFC model

1. Identify sectors to be modelled (households, firms, etc.)
2. Create balance-sheet (BS) of the economy
3. Create transactions-flow matrix (TFM)
4. Write down identities from the TFM:
   i. Use columns to derive budget constraints
   ii. Use also rows with multiple entries
   iii. Identify buffer variables
5. Define behavioural equations and equilibrium conditions

2 Model Accounting

Assumptions

This is a model developed in chapter 4 of Godley and Lavoie (2007). PC stands for portfolio choice, because households can hold their wealth in terms of cash and/or government bills.

Key assumptions are as follows:

- Closed economy
- Four agents: households, “firms”, government, central bank
- Two financial assets: government bills and outside money (cash)
- No investment (accumulation) and no inventories
- Fixed prices and zero net profits
- No banks, no inside money (bank deposits)
- No ecosystem

Balance-sheet

	Households	Firms (production)	Central Bank	Government	Σ
Money (cash)	$+H_h$		$-H_s$		0
Bills	$+B_h$		$+B_{cb}$	$-B_s$	0
Balance (net worth)	$-V_h$			$+V_g$	0
Σ	0	0	0	0	0

Equation (6)

Equation (10)

Notes: A '+' before a magnitude denotes an asset; a '–' denotes a liability.

Transactions-flow matrix

	Households	Firms (production)	Banks	Central Bank	Government	Σ
Consumption	$-C$	$+C$				0
Gov. spending		$+G$			$-G$	0
Income=GDP	$+Y$	$-Y$	Equation (1)			0
Interest payments	$+r_{-1} \cdot B_{h,-1}$			$+r_{-1} \cdot B_{cb,-1}$	$-r_{-1} \cdot B_{s,-1}$	0
CB profits				$-r_{-1} \cdot B_{cb,-1}$	$+r_{-1} \cdot B_{cb,-1}$	0
Taxes	$-T$				$+T$	0
Δ in cash	$-\Delta H_h$			$+\Delta H_s$		0
Δ in bills	$-\Delta B_h$			$-\Delta B_{cb}$	$+\Delta B_s$	0
Σ	0	0	0	0	0	0

Notes: A '+' before a magnitude denotes a receipt or a source of funds; a '–' denotes a payment or a use of funds

Memo: Tobin's portfolio equations

- One of the key behavioural assumptions is that households make a two stage decision:
  1. they decide how much they consume/save out of their income
  2. they decide how to allocate their wealth
- Let us consider 3 different financial assets (A, B and H). Following Brainard and Tobin (1968) and Tobin (1969), portfolio equations are:

$$\frac{A_h}{V_h} = \lambda_{10} + \lambda_{11} \cdot r_A - \lambda_{12} \cdot r_B - \lambda_{13} \cdot r_H - \lambda_{14} \cdot \left(\frac{YD}{V_h}\right) \quad (1)$$

$$\frac{B_h}{V_h} = \lambda_{20} - \lambda_{21} \cdot r_A + \lambda_{22} \cdot r_B - \lambda_{23} \cdot r_H - \lambda_{24} \cdot \left(\frac{YD}{V_h}\right) \quad (2)$$

$$\frac{H_h}{V_h} = \lambda_{30} - \lambda_{31} \cdot r_B - \lambda_{32} \cdot r_B + \lambda_{33} \cdot r_H + \lambda_{34} \cdot \left(\frac{YD}{V_h}\right) \qquad r_H = 0 \text{ and } \lambda_{34} > 0 \quad (3)$$

Memo: Portfolio vertical constraints

- In matrix form:

$$\begin{bmatrix} A_h \\ B_h \\ H_h \end{bmatrix} = \begin{bmatrix} \lambda_{10} \\ \lambda_{20} \\ \lambda_{30} \end{bmatrix} \cdot V_h + \begin{bmatrix} \lambda_{11} & \lambda_{12} & \lambda_{13} \\ \lambda_{21} & \lambda_{22} & \lambda_{23} \\ \lambda_{31} & \lambda_{32} & \lambda_{33} \end{bmatrix} \cdot \begin{bmatrix} r_A \\ r_B \\ r_H \end{bmatrix} \cdot V_h + \begin{bmatrix} \lambda_{14} \\ \lambda_{24} \\ \lambda_{34} \end{bmatrix} \cdot YD$$

- Vertical constraint 1: $\lambda_{10} + \lambda_{20} + \lambda_{30} = 1$, as (the exogenous components of) the total shares of each assets must sum to unity

- Vertical constraint 2:

$$\lambda_{11} + \lambda_{21} + \lambda_{31} = 0$$
$$\lambda_{12} + \lambda_{22} + \lambda_{32} = 0$$
$$\lambda_{13} + \lambda_{23} + \lambda_{33} = 0$$
$$\lambda_{14} + \lambda_{24} + \lambda_{34} = 0$$

The vertical sum of the coefficients in the rates of return matrix must be zero.

Memo: Other portfolio constraints

- The horizontal sum of the coefficients in the rates of return matrix must be zero:

$$\boxed{\lambda_{11} = -(\lambda_{12} + \lambda_{13})}$$
$$\lambda_{22} = -(\lambda_{21} + \lambda_{23})$$
$$\lambda_{33} = -(\lambda_{31} + \lambda_{33})$$

The effect of demand on each asset of an increase in its own rate of interest should match that of a fall in all the other rates (*ceteris paribus*).

- One can also add a simmetry condition:

$$\boxed{\lambda_{12} = \lambda_{21}}$$
$$\lambda_{13} = \lambda_{31}$$
$$\lambda_{23} = \lambda_{32}$$

An increase in the return rate on A generates a drop in B that is of the same size as the drop in A generated by an identical increase in the return rate of B, etc.

Equations

National income:	$Y = C + G$	(1)
Disposable income:	$YD = Y - T + r_{-1} \cdot B_{h,-1}$	(2)
Tax revenue:	$T = \theta \cdot (Y + r_{-1} \cdot B_{h,-1})$	(3)
Household wealth:	$V_h = V_{h,-1} + YD - C$	(4)
Consumption:	$C = \alpha_1 \cdot YD + \alpha_2 \cdot V_{-1}$	(5)
Cash held by households:	$H_h = V_h - B_h$	(6)
Bills held by households:	$B_h = \lambda_0 \cdot V_h + \lambda_1 \cdot V_h \cdot r - \lambda_2 \cdot YD$	(7)
Supply of bills:	$B_s = B_{s,-1} + G - T + r_{-1} \cdot \left(B_{s,-1} - B_{cb,-1}\right)$	(8)
Supply of cash:	$H_s = H_{s,-1} + \Delta B_{cb}$	(9)
Bills held by the central bank:	$B_{cb} = B_s - B_h$	(10)
Interest rate:	$r = \bar{r}$	(11)
Redundant equation:	$H_h = H_s$	

- Identity
- Equilibrium condition
- Behavioural equation

Box 2 How to install *R* and run a toy model

a) Download and install [*R*] (free software)

b) Download and install *R-Studio Desktop* (free version)

c) Alternatively, use Posit Cloud (free online platform for *R* and *Python*)

d) Get familiar with *R* using the Cheat Sheet

e) Download toy models from my GitHub repository

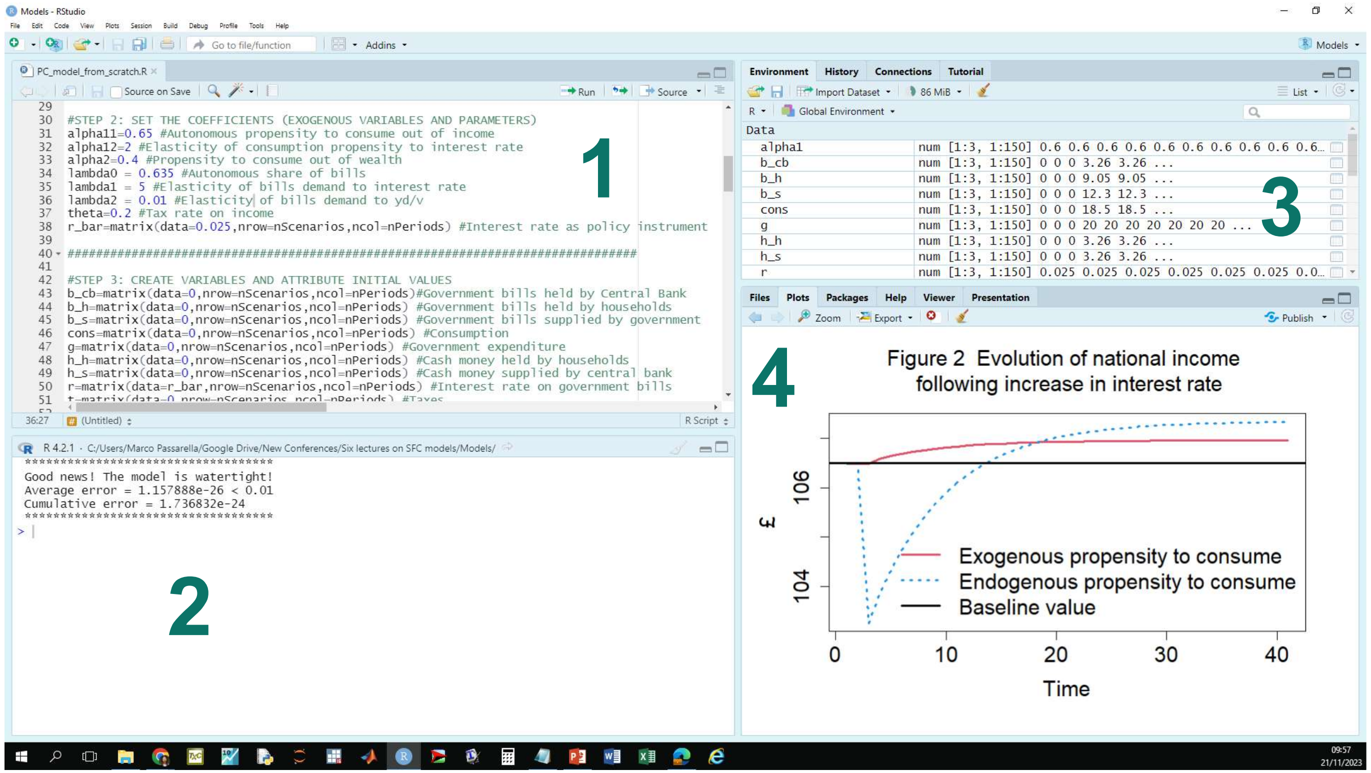
f) Open the file and execute the entire code by clicking Source or run it line by line using Run

g) Check model variables (Data) and coefficients (Values) in the top-right pane, named Global Environment

h) Charts are displayed in the Plots tab in the bottom-right pane

i) Tables and Sankey diagrams are displayed in the Viewer tab in the bottom-right pane (note: always re-run the last coding block to visualise them)

Box 3 Panes in *RStudio*



Tip: if you want to change your background, go to Tools / Global Options / Appearance and then select your favourite settings

1. **Source editor:** opens, edits, and executes program files.
2. **Console or command line:** types codes that are run immediately. Messages are also displayed here.
3. **Environment:** shows objects (data frames, arrays, values, and functions), including variables and coefficients of the model.
4. **Bottom-right pane:**
   - **Files:** file manager
   - **Plots:** displays plots
   - **Packages:** packages manager
   - **Help:** searches for *R* documentation
   - **Viewer:** visualises HTML codes (including tables and Sankey diagrams)
   - **Presentation:** create HTML5 presentations using a combination of *Markdown* and *R*

3 Simulations

Dynamics

Stationary (quasi steady-state) solution: $Y^* = \dfrac{G + r \cdot B_h^* \cdot (1-\theta)}{\theta}$

Tip: how to find the quasi steady-state

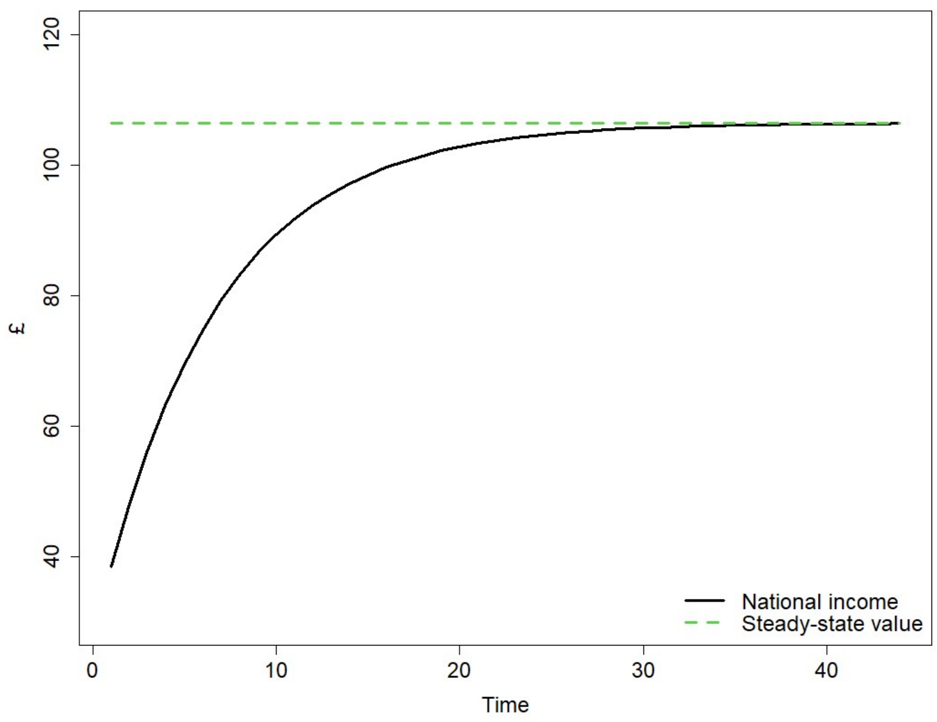
Notice that $C = YD$ and $B_{h,-1} = B_h = B^*$ in steady state.

Use $C = YD$ in equation (1), from which: $Y^* = YD + G$.

Next, use equations (2) and (3) in Y, from which: $Y^* = (Y^* + r \cdot B_h^*) \cdot (1-\theta) + G$.

Next, solve for Y^*.

Figure 1 Evolution of national income following initial governemnt spending



$G = 20$

$r = 0.025$

$\theta = 0.2$

$B_h^* \sim 64.87$

$Y^* \sim 106.49$

BS steady-state values

	Households	Firms (production)	Central Bank	Government	Σ
Money (cash)	$+21.62$		-21.62		0
Bills	$+64.87$		$+21.62$	-86.49	0
Balance (net worth)	-86.49			$+86.49$	0
Σ	0	0	0	0	0

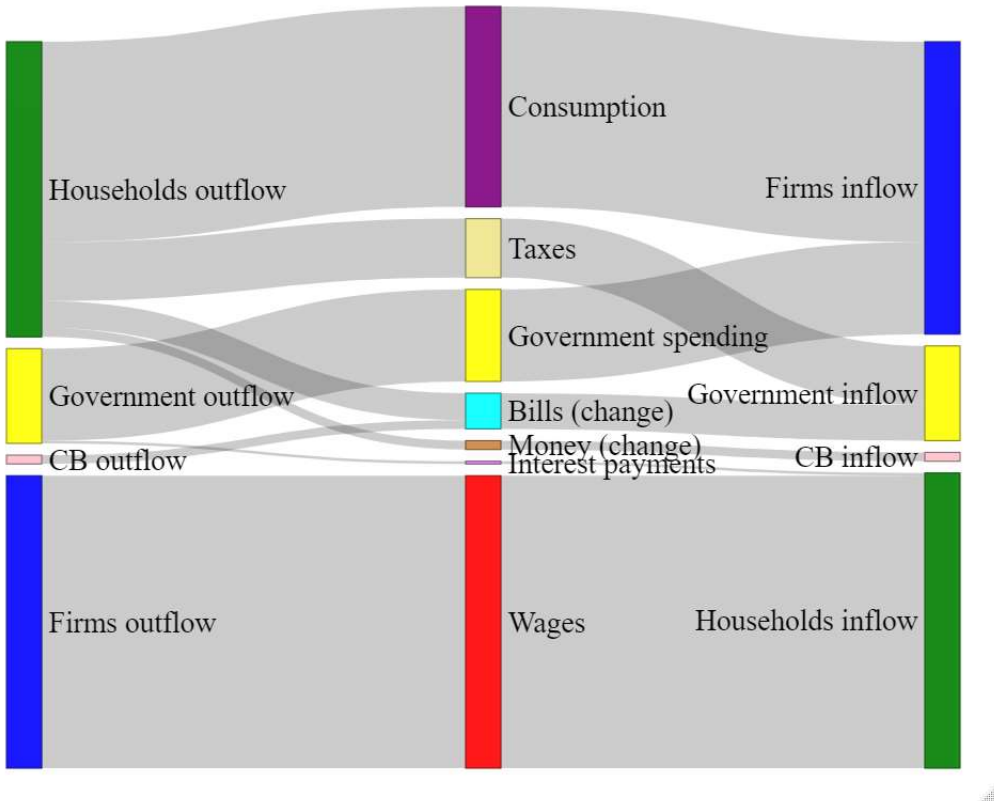
Notes: A '+' before a magnitude denotes an asset; a '–' denotes a liability.

TFM steady-state values

	Households	Firms (production)	Banks	Central Bank	Government	Σ
Consumption	−86.49	+86.49				0
Gov. spending		+20			−20	0
Income=GDP	+106.49	−106.49				0
Interest payments	+1.62			+0.54	−2.16	0
CB profits				−0.54	+0.54	0
Taxes	−21.62				+21.62	0
Δ in cash	0			0		0
Δ in bills	0			0	0	0
Σ	0	0	0	0	0	0

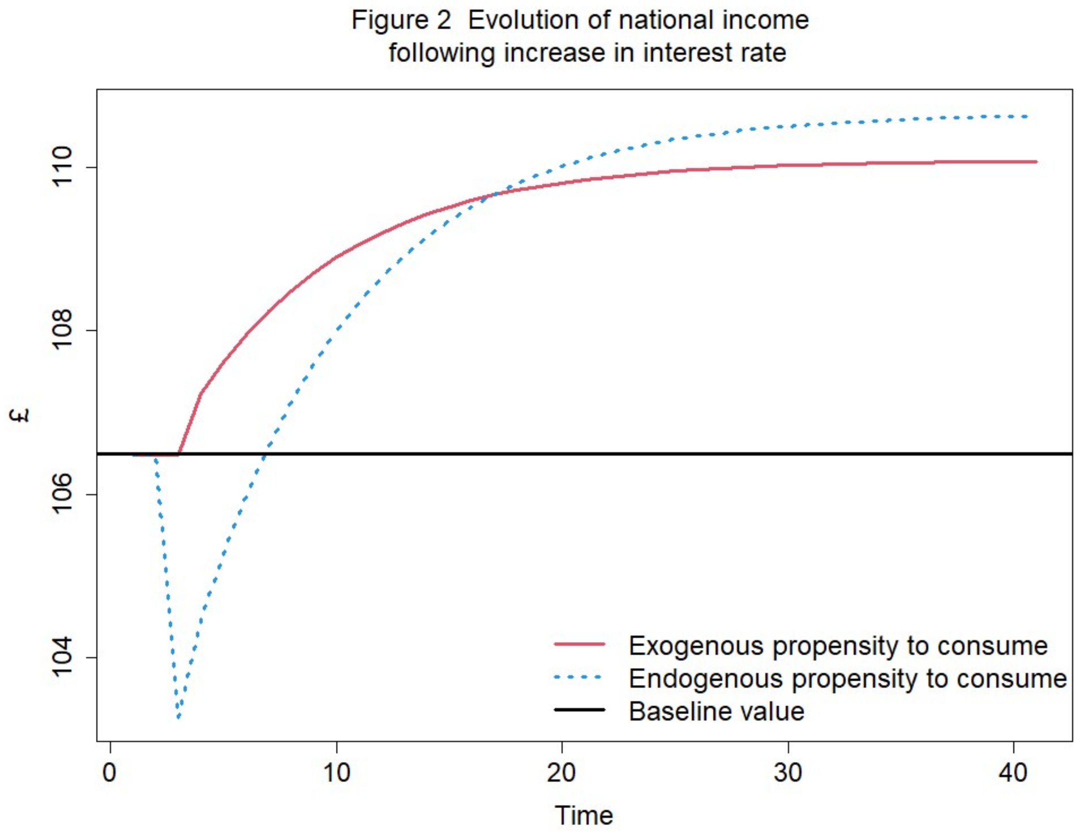
Notes: A '+' before a magnitude denotes a receipt or a source of funds; a '–' denotes a payment or a use of funds

Sankey diagram of transactions (t=5)



Experiment: a loose monetary policy

Higher interest rate on government bonds: $r = 0.025 \rightarrow 0.035$



Scenario *blue*

Additional equation:

$\alpha_1 = \alpha_{11} - \alpha_{12} \cdot r$

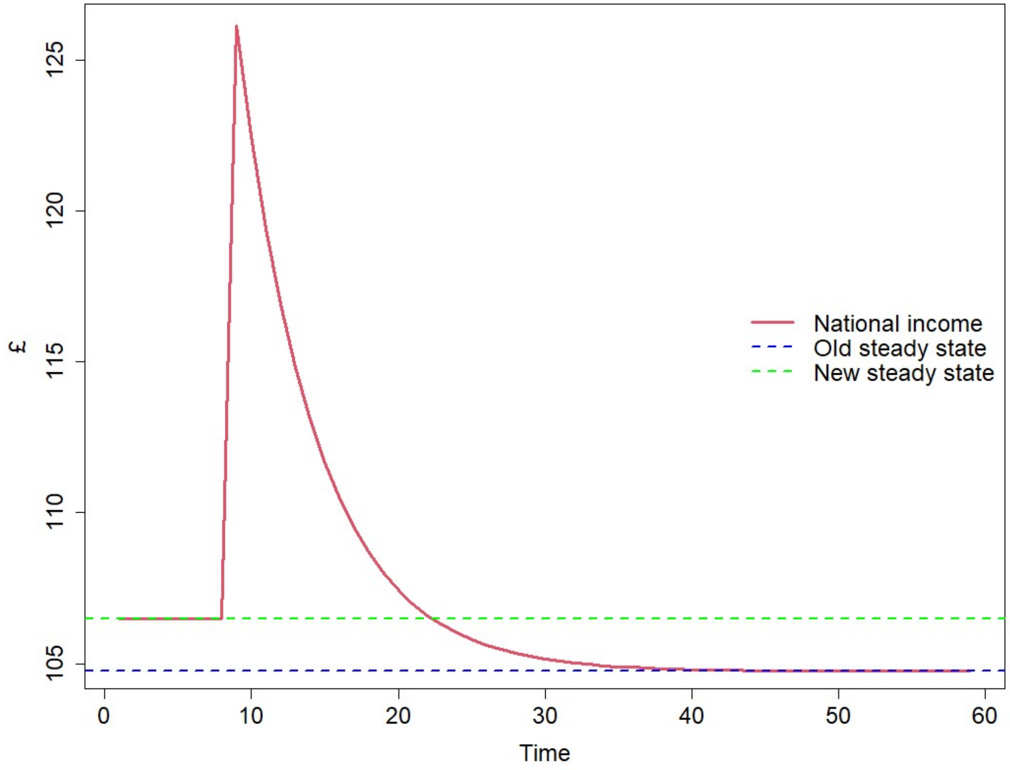
Coefficient values:

$\alpha_{11} = 0.65$

$\alpha_{12} = 2$

Another surprise: no paradox of thrift!

Figure 3 Rise and fall of national income (GDP) following an increase in the propensity to consume out of expected disposable income



Note. The consumption function is:

$C = \alpha_1 \cdot YD + \alpha_2 \cdot V_{-1}$

which, under the steady state, becomes:

$YD = \alpha_1 \cdot YD + \alpha_2 \cdot V$

from which we obtain:

$\frac{V}{YD} = \alpha_3, \quad$ with: $\alpha_3 = \frac{1-\alpha_1}{\alpha_2}$

Households have a target level of wealth:

$V^T = \alpha_3 \cdot YD$

where α_3 is their stock-flow norm.

If α_1 or α_2 increase then α_3 reduces.

It can be shown that $Y^* = f^+(\alpha_3)$. The reason is that a higher V implies a higher B_h, which implies higher interest payments from the government, which imply a higher income!

Introducing adaptive expectations

Figure 4 Rise and fall of national income (GDP) following an increase in the propensity to consume out of expected disposable income

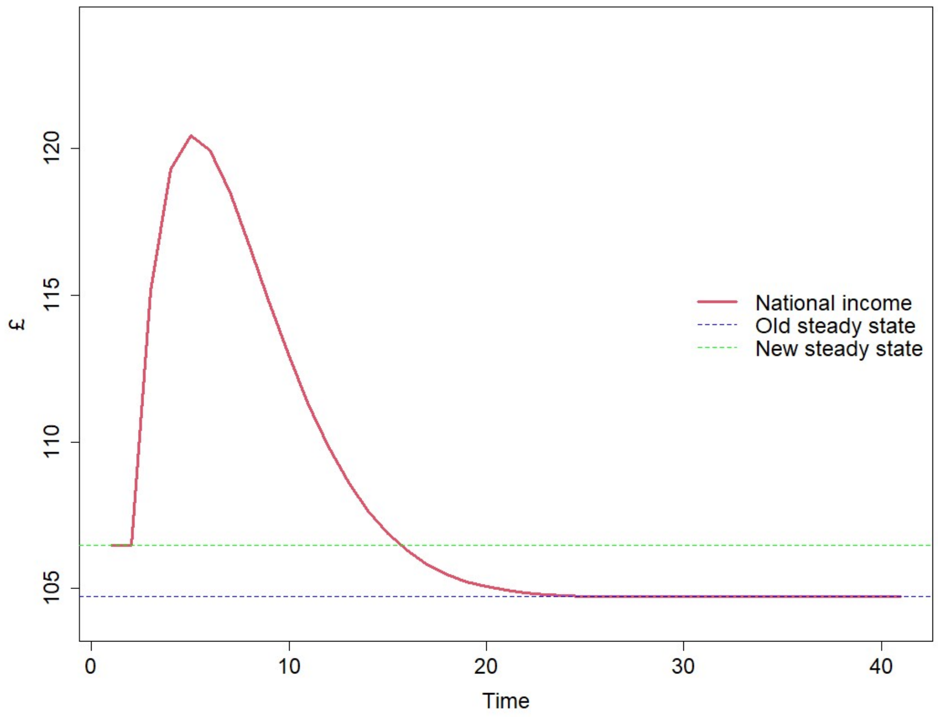
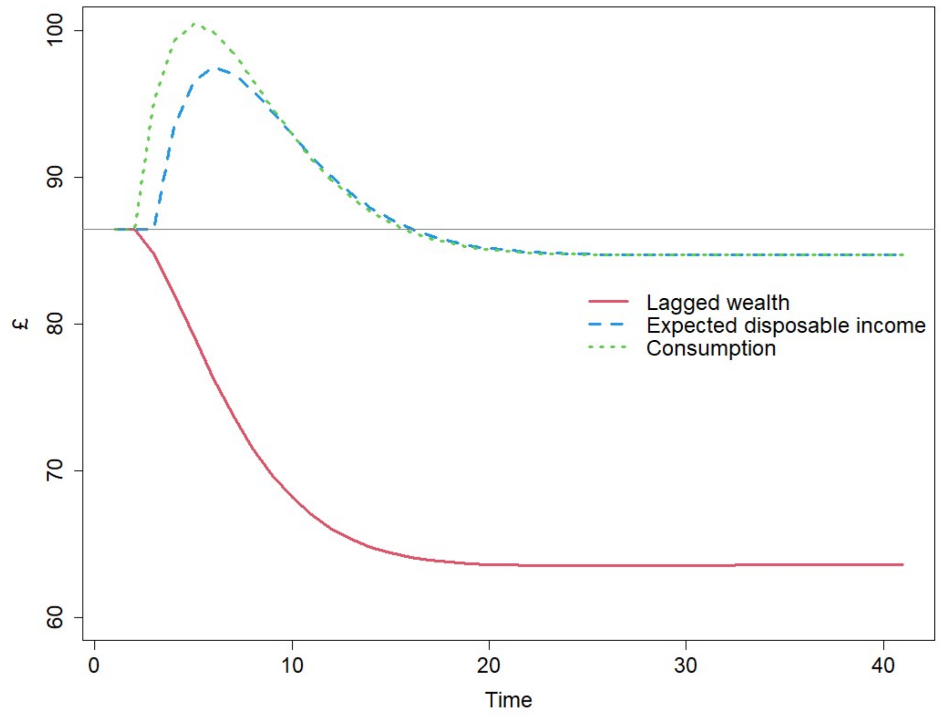
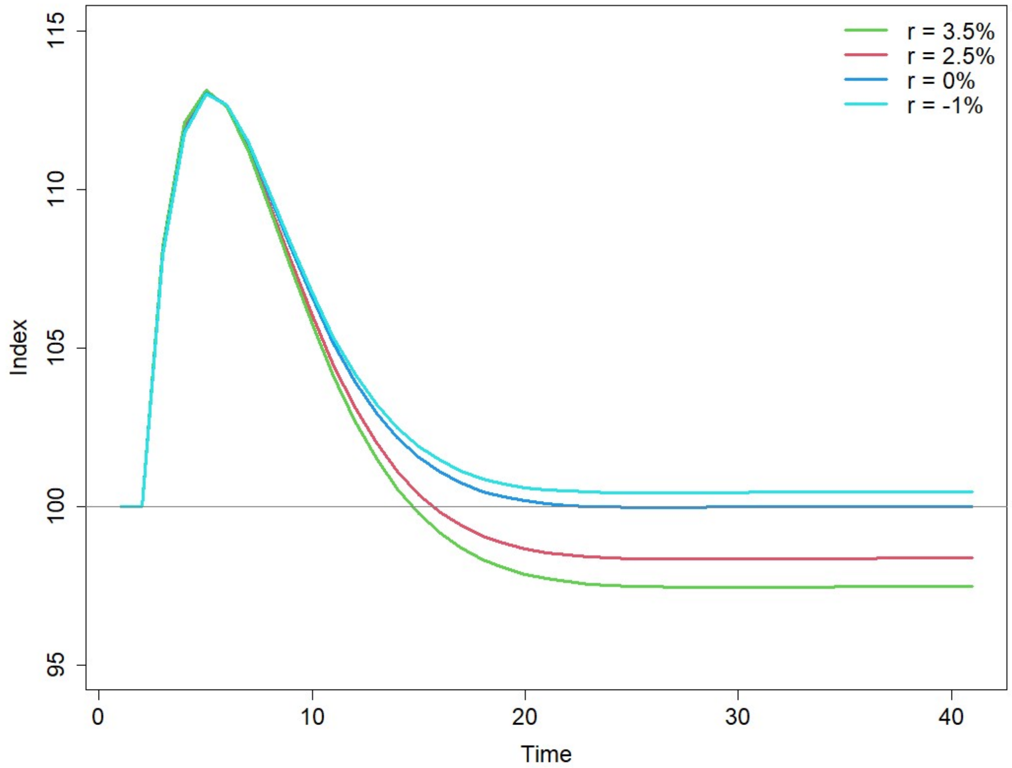


Figure 5 Evolution of C, expected YD and V following an increase in the propensity to consume



New steady states for different values of $\bar{r}$

Figure 6 Rise and fall of national income (GDP) following an increase in the propensity to consume out of expected disposable income



4 Modelling PC in *R*

Other shocks

- Let us code the model in an *R* environment and perform the following experiments:
  a) Δ in tax rate
  b) Δ in propensities to consume
  c) Δ in portfolio coefficients (bills)
  d) Δ in interest rate (paradoxical effect)
  e) Δ in interest rate
  f) New equation for consumption
  g) Introduce expectations
- Go to the code...

Useful web resources for SFC modellers

Authors	Description	Link
Alessandro Bramucci	**Interactive Macro -** Website collecting a series of simulators programmed in R and Shiny of some famous macroeconomic textbook models.	Link
Alessandro Caiani	**JMAB -** Simulation tool designed (with Antoine Godin) for AB-SFC macroeconomic modeling.	Link
Yannis Dafermos	**DEFINE -** Ecological stock-flow consistent model that analyses the interactions between the ecosystem, the financial system and the macroeconomy (developed with Maria Nikolaidi and Giorgos Galanis).	Link
Michal Gamrot	**Godley package -** R package for simulating SFC (stock-flow consistent) models.	Link
Antoine Godin	**SFC codes -** R and Python codes collected from seminars and lectures.	Link
Andrea Luciani	**Bimets package -** R package developed with the aim to ease time series analysis and to build up a framework that facilitates the definition, estimation, and simulation of simultaneous equation models.	Link
Joao Macalos	**SFCR package -** R package providing an intuitive and tidy way to estimate stock-flow consistent models.	Link
Jo Michell	**SFC codes -** R and Python codes collected from seminars and lectures.	Link
Franz Prante and Karsten Kohler	**DIY Macroeconomic Model Simulation -** Platform providing an open source code repository and online script for macroeconomic model simulation.	Link
Marco Veronese Passarella (marxianomics)	**SFC codes -** R, Python, Matlab and EViews codes collected from papers, seminars and lectures.	Link
Marco Veronese Passarella (GitHub)	**SFC codes -** R, Python, Matlab and EViews codes collected from papers, seminars and lectures.	Link
Gennaro Zezza	**sfc.models.net -** Repository containing original EViews (and Excel) codes that replicate experiments from Godley and Lavoie's "Monetary Economics", and additional (R and EViews) codes from the SFC literature.	Link

Selected references

KEY READINGS

- W. Godley and M. Lavoie (2007). *Monetary Economics. An Integrated Approach to Credit, Money, Income, Production and Wealth*. Palgrave Macmillan, chapters 1, 2, 3, 4, 7.

ADDITIONAL READINGS

- W. Godley (1999). Seven Unsustainable Processes. *Levy Institute Strategic Analysis*, January 1999.
- C.H. Dos Santos (2006). Keynesian Theorising During Hard Times: Stock-Flow Consistent Models as an Unexplored 'Frontier' of Keynesian Macroeconomics. *Cambridge Journal of Economics*, 30 (4), 541-565.
- M. Nikiforos and G. Zezza (2017). Stock-Flow Consistent macroeconomic Models: A Survey. *Journal of Economic Surveys*, 31 (5), 1204-1239.
- Emilio Carnevali, Matteo Deleidi, Riccardo Pariboni, Marco Veronese Passarella (2019). Stock-Flow Consistent Dynamic Models: Features, Limitations and Developments. In: Philip Arestis, Malcolm Sawyer (eds.): *Frontiers of Heterodox Macroeconomics*, Palgrave Macmillan, 2019, pp. 223-276.

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Thanks

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