Introduction to SFC Dynamic Models

Lecture E Ecological and Input-Output SFC Models

Marco Veronese Passarella

Department of Industrial and Information Engineering and Economics
University of L'Aquila – Italy

Leeds University Business School
University of Leeds – UK

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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
C. A Toy Model with Bank Money and Fixed Capital
D. Multi-Country SFC Models
E. **Ecological and Input-Output SFC Models**
    1. **Introduction**
    2. **Accounting of Model IO-PC**
    3. **Simulations of Model IO-PC**
    4. **Introducing the ecosystem**
F. Empirical SFC Models (using *Bimets*)

1 Introduction

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

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)

New frontiers of SFC models

- Although the origins of ecological macroeconomics can be traced back to the inception of economics itself, early SFC models for economic research did not incorporate the ecosystem.
- This gap was bridged in the late 2010s (Dafermos, Nikolaidi, and Galanis, 2017, 2018; Jackson and Victor, 2015). The primary characteristic of ecological SFC models is their integration of monetary variables (following Godley and Lavoie, 2007) with physical variables (in line with Georgescu-Roegen, 1971) in a consistent manner. Several ECO-SFC models have been developed since then.
- In contrast, there are currently only a few prototypes of input-output SFC models, despite some progress made in recent years (Berg, Hartley, and Richters, 2015; Jackson and Jackson, 2021, 2023; Valdecantos, 2023).
- However, this step is essential for analysing the interaction of the ecosystem with the economy (Hardt and O'Neill, 2017) and technical progress (Veronese Passarella, 2023).

2 Accounting of Model IO-PC

Assumptions of Model IO-PC

Model IO-PC is an IO extension of Model PC, where IO stands for input-output structure.

Additional assumptions are as follows:

- Two industries
- Circulating capital only
- Fixed technical coefficients
- 1 industry = 1 technique = 1 product
- Prices are fixed
- Exogenous composition of consumption and government spending

Balance-sheet of Model IO-PC

	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

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

Transactions-flow matrix of Model IO-PC

	Households	Firms (production)	Banks	Central Bank	Government	Σ
Consumption	$-C$	$+C$				0
Gov. spending		$+G$			$-G$	0
Income=GDP	$+Y$	$-Y$				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

Input-output table of Model IO-PC

		Demand for inputs		Final demand	Output
		Industry 1	Industry 2		
Production	Industry 1	$p_1 \cdot a_{11} \cdot x_1$	$p_2 \cdot a_{12} \cdot x_2$	$p_1 \cdot d_1$	$p_1 \cdot x_1$
	Industry 2	$p_2 \cdot a_{21} \cdot x_1$	$p_2 \cdot a_{22} \cdot x_2$	$p_2 \cdot d_2$	$p_2 \cdot x_2$
	Value added	$p_1 \cdot x_1 - (p_1 \cdot a_{11} \cdot x_1 + p_2 \cdot a_{21} \cdot x_1)$	$p_2 \cdot x_2 - (p_2 \cdot a_{12} \cdot x_2 + p_2 \cdot a_{22} \cdot x_2)$	$\mathbf{p}^{\mathrm{T}} \cdot \mathbf{d} = Y$	
	Output	$p_1 \cdot x_1$	$p_2 \cdot x_2$		$\mathbf{p}^{\mathrm{T}} \cdot \mathbf{x}$

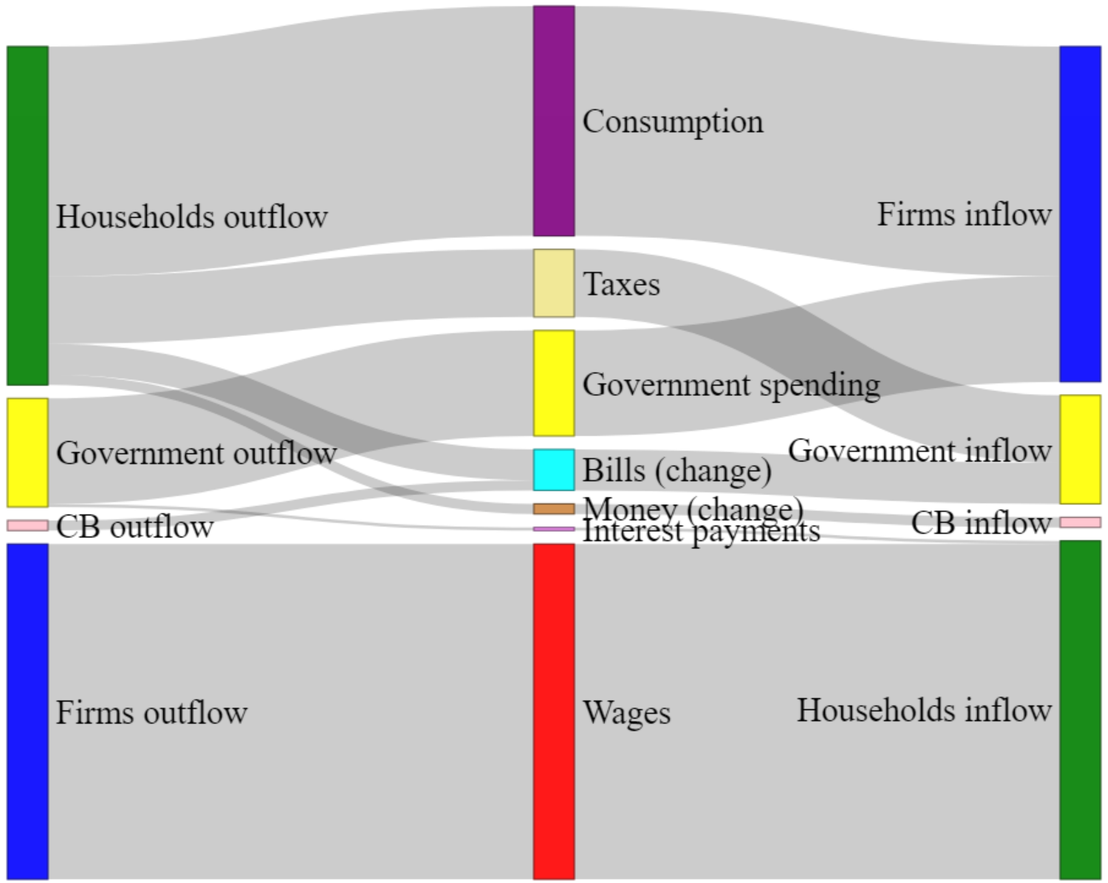
Additional equations of Model IO-PC

Unit prices:	$\mathbf{p} = \overline{\mathbf{p}}$	(12)
Compos. of real consumption:	$\boldsymbol{\beta}_{\mathbf{c}} = \overline{\boldsymbol{\beta}}_{\mathbf{c}}$	(13)
Compos. of real gov. spending:	$\boldsymbol{\beta}_{\mathbf{g}} = \overline{\boldsymbol{\beta}}_{\mathbf{g}}$	(14)
Average consumer price:	$p_c = \mathbf{p}^{\mathrm{T}} \cdot \boldsymbol{\beta}_{\mathbf{c}}$	(15)
Average price for government:	$p_g = \mathbf{p}^{\mathrm{T}} \cdot \boldsymbol{\beta}_{\mathbf{g}}$	(16)
Real final demand:	$\mathbf{d} = \boldsymbol{\beta}_{\mathbf{c}} \cdot c + \boldsymbol{\beta}_{\mathbf{g}} \cdot g$	(17)
Real gross output:	$\mathbf{x} = \mathbf{A} \cdot \mathbf{x} + \mathbf{d}$, with: $\mathbf{A} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}$	(18)
National income:	$Y = \mathbf{p}^{\mathrm{T}} \cdot \mathbf{d}$	(1.A)
Real consumption:	$c = \alpha_1 \cdot \left(\frac{YD}{p_c} - \pi \cdot \frac{V_{-1}}{p_c} \right) + \alpha_2 \cdot \frac{V_{-1}}{p_{c,-1}}$	(19)
Nominal consumption:	$C = p_c \cdot c$	(5.A)
Nominal gov. spending:	$G = p_g \cdot g$	(20)

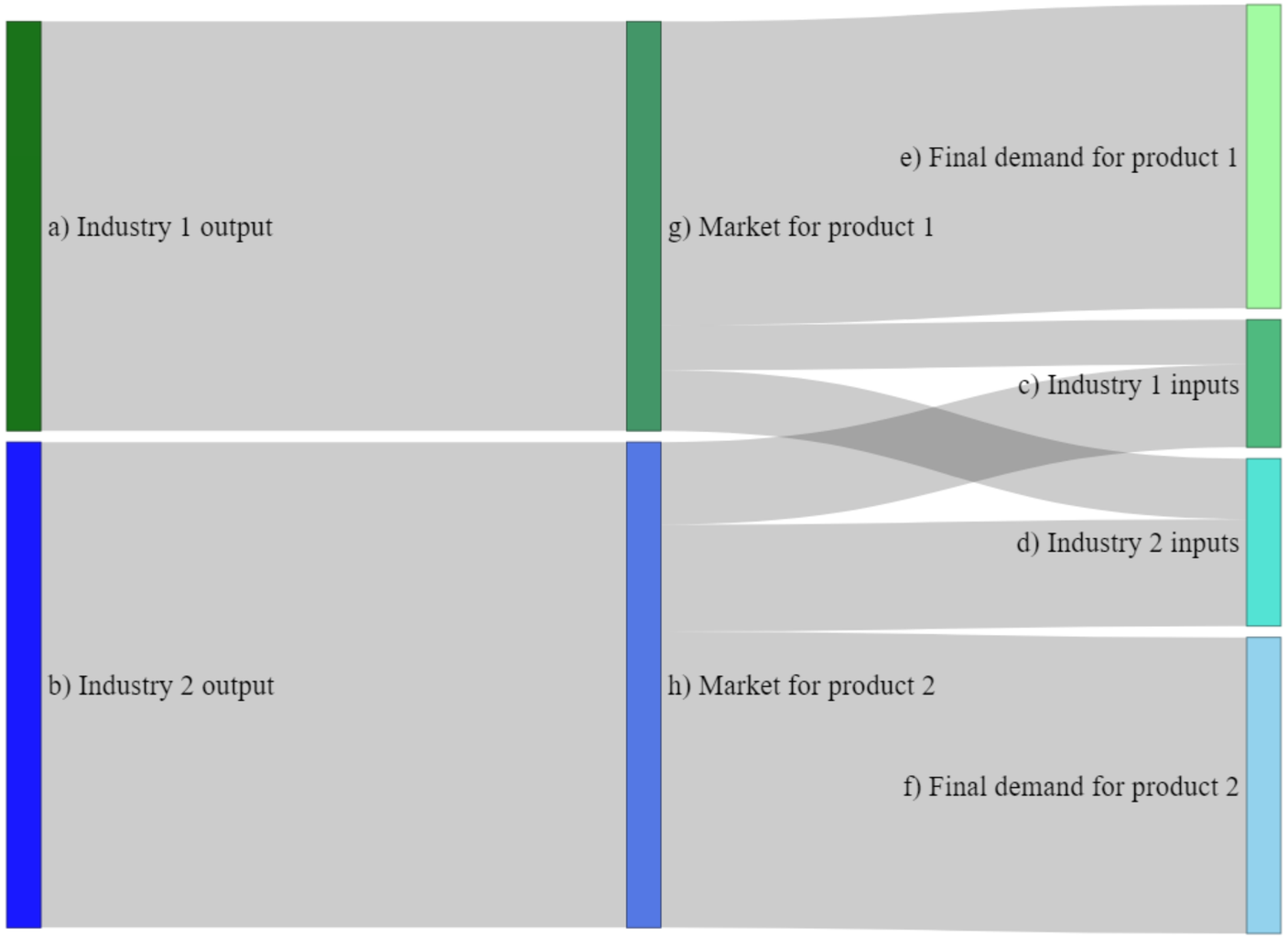
- Identity
- Equilibrium condition
- Behavioural equation

3 Simulations of Model IO-PC

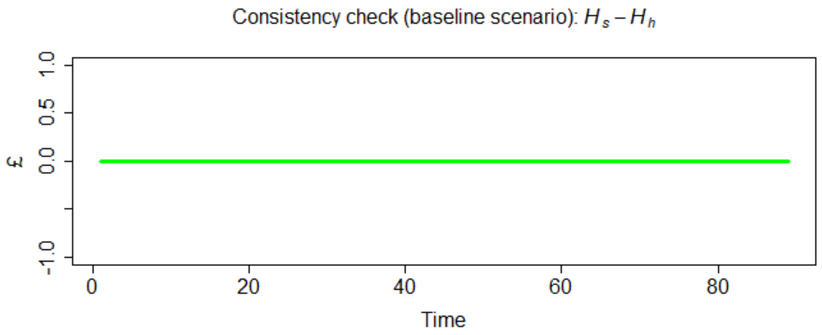
Sankey diagram of transactions (t=5)

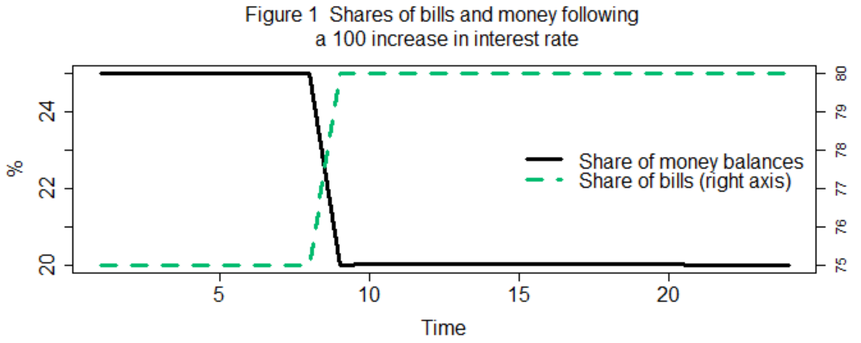


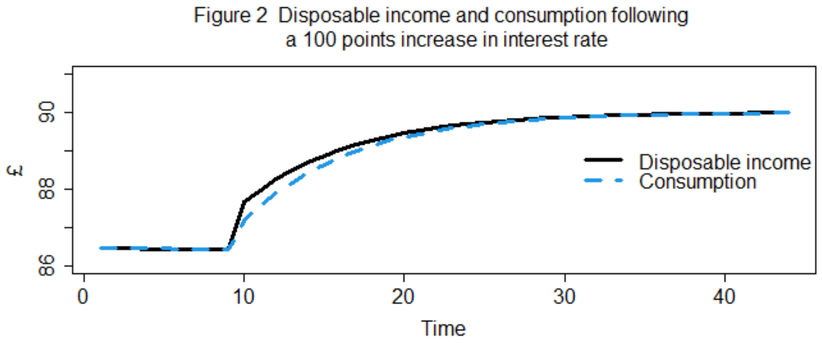
Industrial interdependencies (t=5)

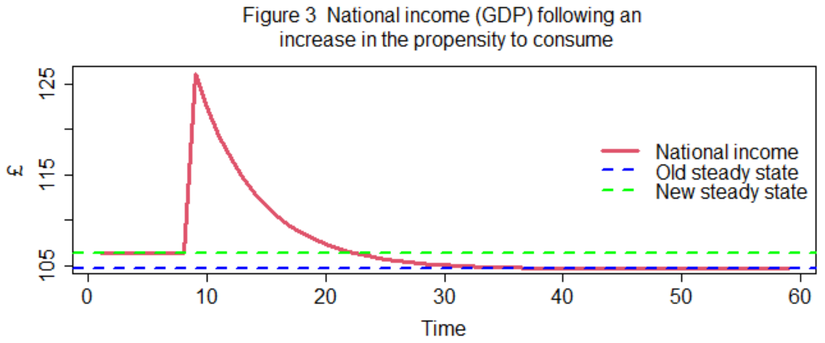


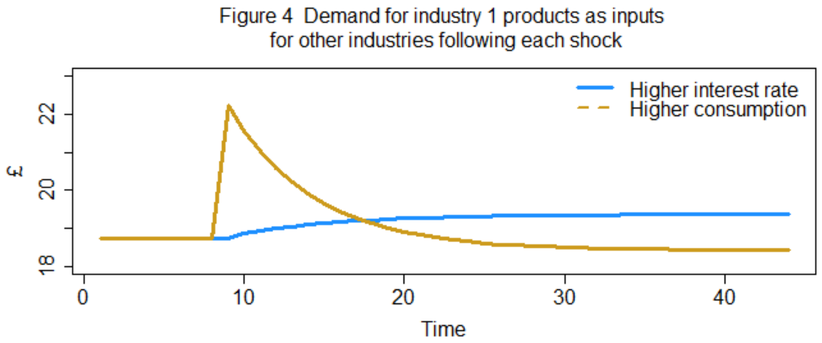
Dynamics of Model IO-PC

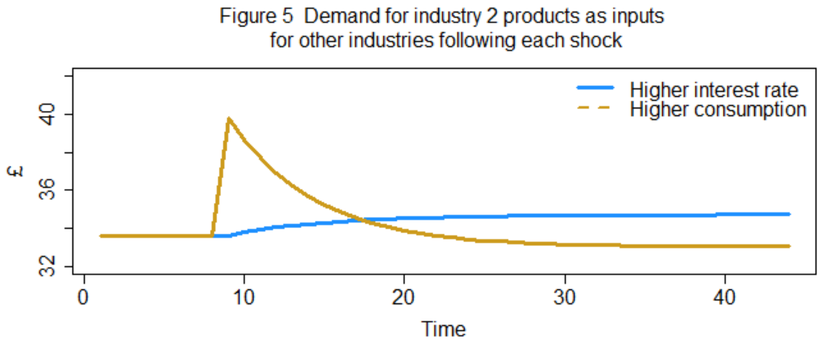












Dynamics of Model IO-PC (cont'd)

Figure 6 Production of industry 1 following shock to consumption

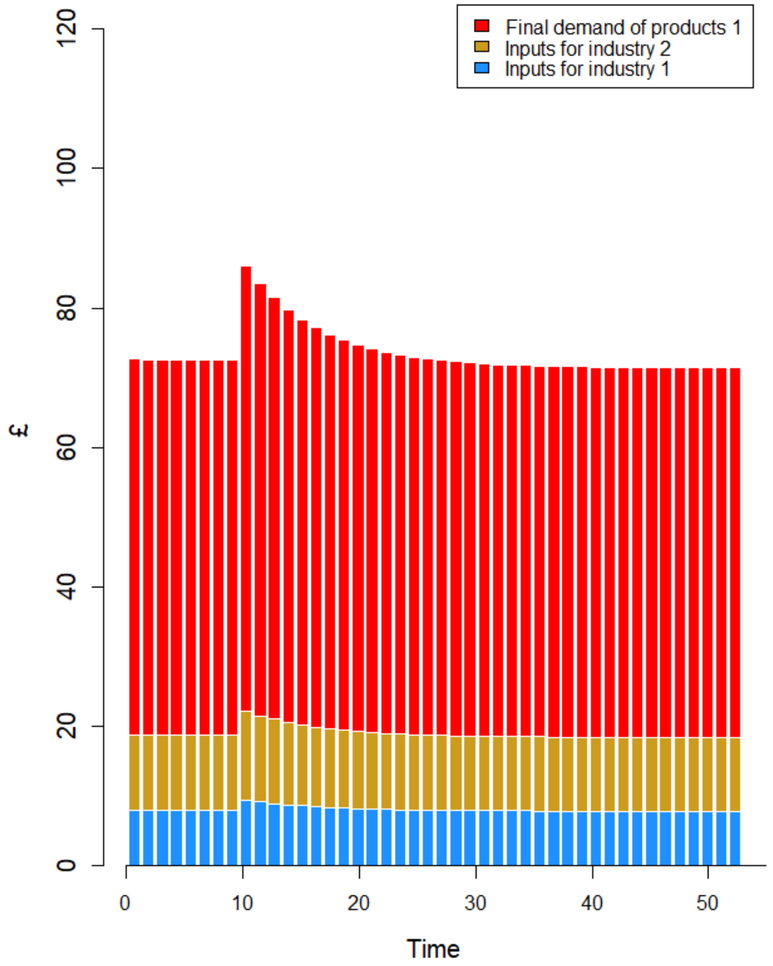
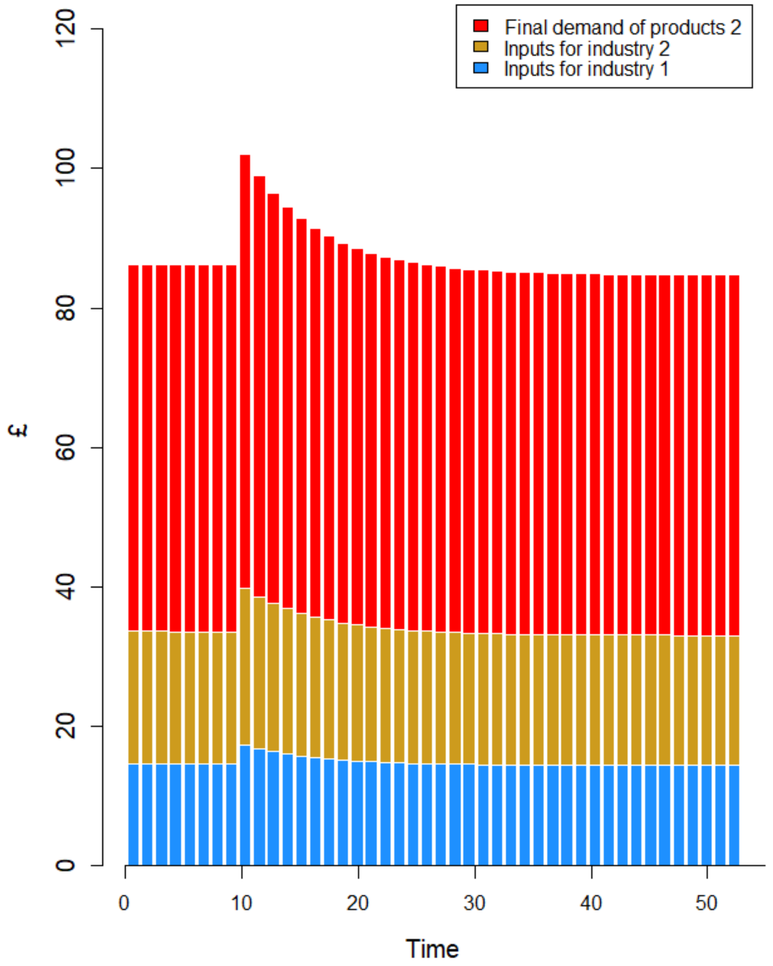
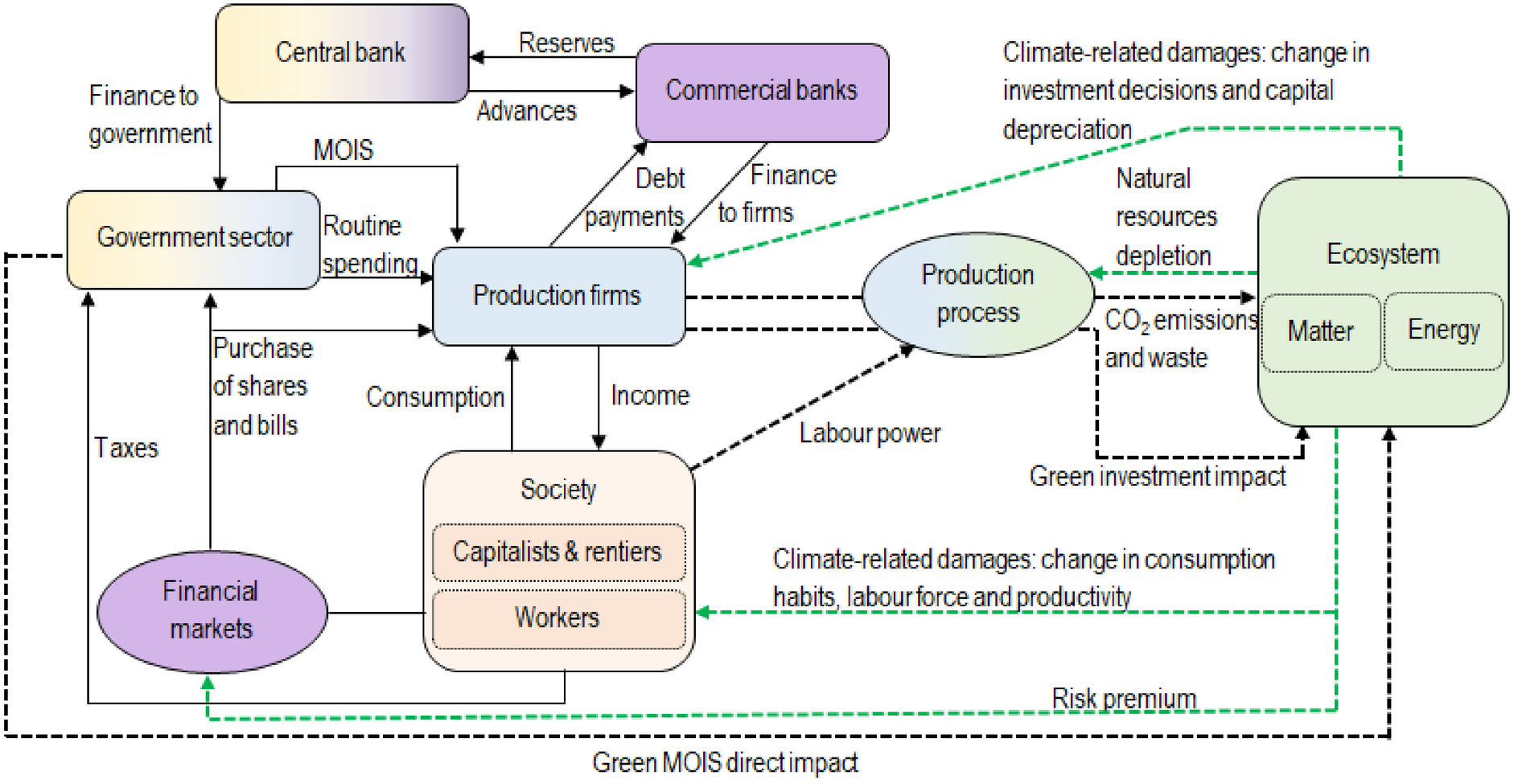


Figure 7 Production of industry 2 following shock to consumption



4 Introducing the ecosystem

Towards a comprehensive model



Source: Emilio Carnevali, Matteo Deleidi, Riccardo Pariboni, and Marco Veronese Passarella (2023)

Additional assumptions of Model ECO-PC

Model ECO-PC is an ecological extension of the IO-PC model, where ECO stands for ecological. Additional assumptions are as follows:

- 2 types of reserves: matter and energy
- 2 types of energy: renewable and non-renewable
- Resources are converted into reserves at a certain rate
- Industrial CO2 emissions are associated with the use of non-renewable energy
- Atmospheric temperature is a growing function of CO2 emissions
- Both goods from industry 1 and industry 2 can be durable or non-durable
- A share of durable goods (hence socio-economic stock) is discarded in every period
- Both waste and emissions are produced only by the firm sector

Physical flow matrix of ECO-PC

	Natural reserves	
	Matter (Gt)	Energy (EJ)
Inputs		
Extracted matter	$+mat$	
Recycled socio-economic stock	$+rec$	
Renewable energy		$+ren$
Non-renewable energy	$+cen$	$+nen$
Oxygen	$+o2$	
Outputs		
Industrial CO2 emissions	$-emis$	
Discarded socio-economic stock	$-dis$	
Dissipated energy		$-en$
Change in socio-economic stock	$-\Delta k_h$	
Total	0	0

Source: my elaboration on Dafermos, Nikolaidi and Galanis (2017)

Physical stock-flow matrix of ECO-PC

	Material reserves	Energy reserves	CO2 concentration	Socio-economic stock
Initial stock	$k_{m,-1}$	$k_{e,-1}$	$CO2_{-1}$	$k_{h,-1}$
Resources converted into reserves	$+conv_m$	$+conv_e$		
CO2 emissions			$+emis$	
Production of material goods				$+x_{mat}$
Extraction of matter / use of energy	$-mat$	$-en$		
Destruction of socio-economic stock				$-dis$
Final stock	k_m	k_e	$CO2$	k_h

Source: my elaboration on Dafermos, Nikolaidi and Galanis (2017). Notes: matter = GT; energy = EJ.

Simulations of Model ECO-PC

Figure 1 National income (GDP) following climate-change induced reduction in propensity to consume

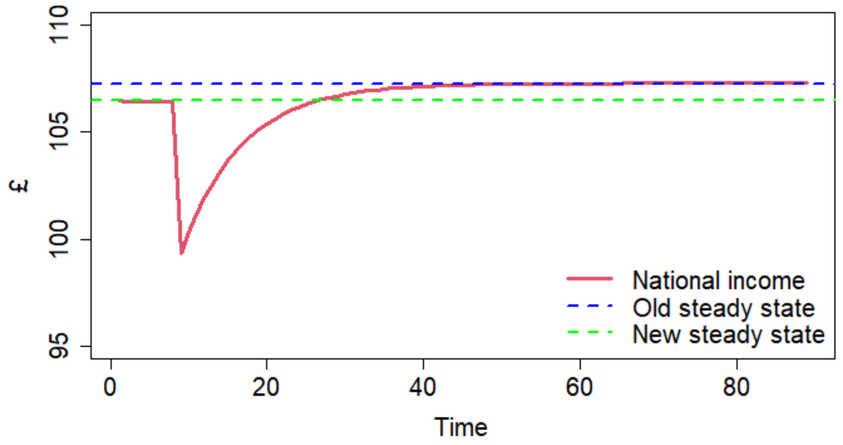


Figure 2 CO2 emissions following climate-change induced reduction in propensity to consume

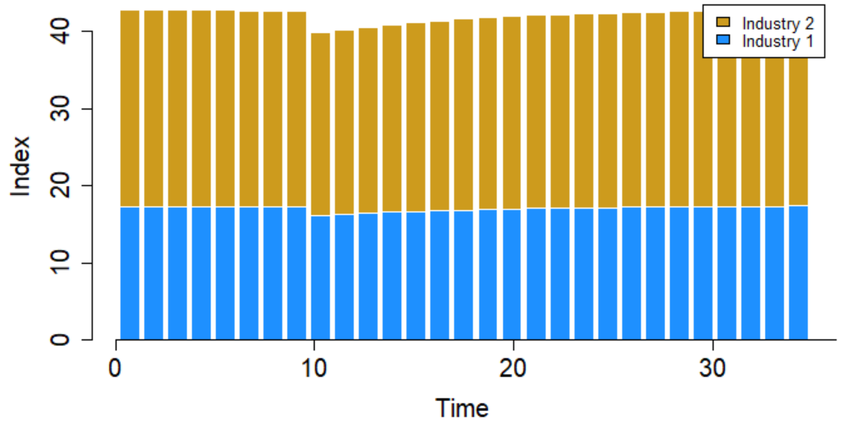


Figure 3 Reserves depletion rates following climate-change induced reduction in propensity to consume

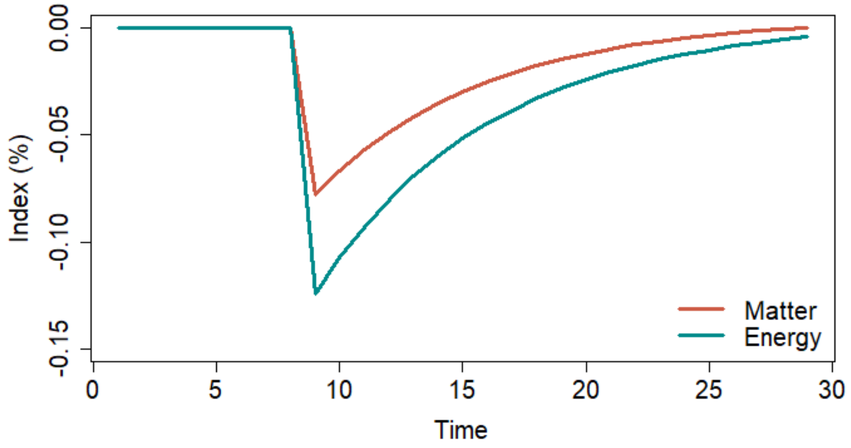
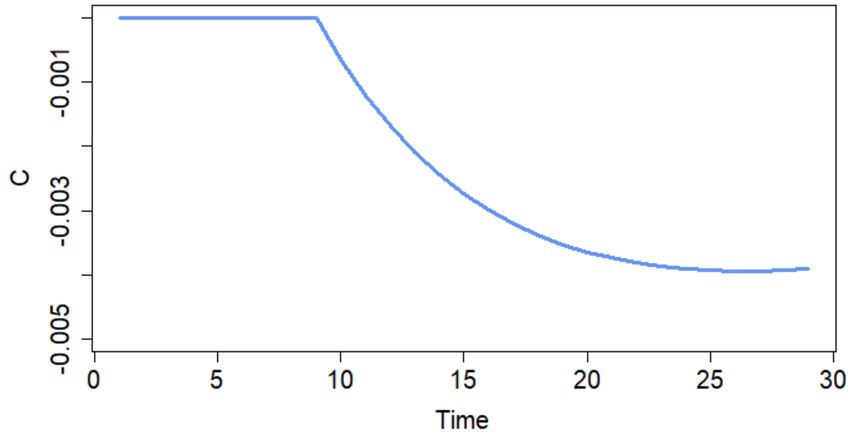


Figure 4 Change in atm. temperature following climate-change induced reduction in propensity to consume



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

For information, contact: marco.veronesepassarella@univaq.it