Stock-flow consistent modelling and ecological macroeconomics

Yannis Dafermos, SOAS University of London

Maria Nikolaidi, University of Greenwich

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Introduction

- Over the last decade, **stock-flow consistent** (SFC) modelling has become a very popular approach in heterodox macro modelling (see Caverzasi and Godin, 2015; Nikiforos and Zezza, 2017, Carnevali et al., 2019).
- The SFC approach has proved successful in formulating the complex interactions between the **financial** and the **real** spheres of the economy.
- This approach has its origins to the work of the **Yale group** of James Tobin and the **Cambridge Economic Policy Group** of Wynne Godley that used SFC structures to analyse the US and the UK economy in the 1970s and the 1980s.

Introduction

- There is currently a lot of research on **theoretical SFC modelling**. This is partly explained by the fact that SFC models are characterised by a high flexibility that allows them to be deployed for the analysis of a wide range of topics.
- There is also research on **empirical SFC modelling** (for a review of country-specific models see Zezza, 2019). However, the empirical SFC literature is much less developed than the theoretical one.
- SFC models are often viewed as **alternative models to the DSGE ones** (especially when they are combined with agent-based structures).
- Recently, SFC models have been used for the analysis of **ecological macroeconomic** issues.

Outline

1. Key features of SFC models
2. Steps in developing an SFC model
3. Incorporating ecological aspects into SFC models
4. Conclusion

1. Key features of SFC models

(1) There are no black holes

'Everything comes from somewhere and goes somewhere'. This is ensured by using two matrices: (i) the balance sheet matrix and (ii) the transactions flow matrix.

(2) The financial and the real spheres are integrated

Following the post-Keynesian tradition on the non-neutrality of money and finance, the SFC models explicitly formulate the various links between financial and real variables.

(3) Behavioural equations are based on post-Keynesian assumptions

The behavioural equations (like consumption and investment functions) are constructed using primarily post-Keynesian theories.

2. Steps in developing an SFC model

Steps in developing an SFC model:

- **Step 1:** Construct the balance sheet matrix.
- **Step 2:** Construct the transactions flow matrix.
- **Step 3:** Write down the identities from the transactions flow matrix. Use the columns (which reflect the budget constraints) and the rows with more than two entries. Identify the buffer variables in the identities.
- **Step 4:** Identify the variables that need to be determined based on behavioural equations. Select your behavioural equations.
- **Step 5:** Put together the identities and the behavioural equations.

2. Steps in developing an SFC model (example)

Suppose that we have an economy with the following features:

- There are four sectors: firms, households, banks and a central bank.
- **Firms** make investment by using retained profits, loans and equity. A part of firms' profits is distributed to households.
- **Households** accumulate savings in the form of deposits and equity.
- **Banks** provide firm loans by creating deposits. Banks' profits are distributed to households.
- **Central bank** holds advances on the asset side of its balance sheet and high-powered money on the liability side.

This is a model with both private bank money and central bank money.

2. Steps in developing an SFC model (example)

- **Step 1:** Construct the balance sheet matrix.

	Households	Firms	Commercial banks	Central bank	Total
Deposits	$+D_t$		$-D_t$		0
Loans		$-L_t$	$+L_t$		0
Equities	$+p_{et}e_t$	$-p_{et}e_t$			0
Capital		$+K_t$			$+K_t$
High-powered money			$+HPM_t$	$-HPM_t$	0
Advances			$-A_t$	$+A_t$	0
Total (net worth)	$+V_{Ht}$	$+V_{Ft}$	0	$+V_{CBt}$	$+K_t$

2. Steps in developing an SFC model (example)

- **Step 2:** Construct the transactions flow matrix.

	Households	Firms		Commercial banks		Central bank		Total
		Current	Capital	Current	Capital	Current	Capital	
Consumption	$-C_t$	$+C_t$						0
Investment		$+I_t$	$-I_t$					0
Wages	$+W_t$	$-W_t$						0
Firms' profits	$+DP_t$	$-TP_t$	$+RP_t$					0
Banks' profits	$+BP_t$			$-BP_t$				0
Central bank's profits						$-CBP_t$	$+CBP_t$	0
Interest on deposits	$+int_D D_{t-1}$			$-int_D D_{t-1}$				0
Interest on loans		$-int_L L_{t-1}$		$+int_L L_{t-1}$				0
Interest on advances				$-int_A A_{t-1}$		$+int_A A_{t-1}$		0
Change in deposits	$-\Delta D_t$				$+\Delta D_t$			0
Change in loans			$+\Delta L_t$		$-\Delta L_t$			0
Change in equities	$-p_{et}\Delta e_t$		$+p_{et}\Delta e_t$					0
Change in high-powered money					$-\Delta HPM_t$		$+\Delta HPM_t$	0
Change in advances					$+\Delta A_t$		$-\Delta A_t$	0
Total	0	0	0	0	0	0	0	0

2. Steps in developing an SFC model (example)

- **Step 3:** Write down the identities from the transactions flow matrix. Use the columns (which reflect the budget constraints) and the rows with more than two entries. Identify the buffer variables in the identities.

	Households	Firms		Commercial banks		Central bank		Total
		Current	Capital	Current	Capital	Current	Capital	
Consumption	$-C_t$	$+C_t$						0
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Banks' profits	$+BP_t$			$-BP_t$				0
Central bank's profits						$-CBP_t$	$+CBP_t$	0
Interest on deposits	$+int_D D_{t-1}$			$-int_D D_{t-1}$				0
Interest on loans		$-int_L L_{t-1}$		$+int_L L_{t-1}$				0
Interest on advances				$-int_A A_{t-1}$		$+int_A A_{t-1}$		0
Change in deposits	$-\Delta D_t$				$+\Delta D_t$			0
Change in loans			$+\Delta L_t$		$-\Delta L_t$			0
Change in equities	$-p_{et}\Delta e_t$		$+p_{et}\Delta e_t$					0
Change in high-powered money					$-\Delta HPM_t$		$+\Delta HPM_t$	0
Change in advances					$+\Delta A_t$		$-\Delta A_t$	0
Total	0	0	0	0	0	0	0	0

Question: In your view, which should be the **buffer variable** in the capital account of firms?

a) Loans (*L*)

b) Investment (*I*)

$$\Delta D_t = Y_{Dt} - C_t - p_{et}\Delta e_t$$

2. Steps in developing an SFC model (example)

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Central bank's profits						$-CBP_t$	$+CBP_t$	0
Interest on deposits	$+int_D D_{t-1}$			$-int_D D_{t-1}$				0
Interest on loans		$-int_L L_{t-1}$		$+int_L L_{t-1}$				0
Interest on advances				$-int_A A_{t-1}$		$+int_A A_{t-1}$		0
Change in deposits	$-\Delta D_t$				$+\Delta D_t$			0
Change in loans			$+\Delta L_t$		$-\Delta L_t$			0
Change in equities	$-p_{et}\Delta e_t$		$+p_{et}\Delta e_t$					0
Change in high-powered money					$-\Delta HPM_t$		$+\Delta HPM_t$	0
Change in advances					$+\Delta A_t$		$-\Delta A_t$	0
Total	0	0	0	0	0	0	0	0

$$\Delta L_t = I_t - RP_t - p_{et}\Delta e_t \qquad CBP_t = int_A A_{t-1}$$

$$TP_t = C_t + I_t - W_t - int_L L_{t-1} \qquad \Delta A_t = \Delta HPM_t + \Delta L_t - \Delta D_t$$

$$\Delta D_t = Y_{Dt} - C_t - p_{et}\Delta e_t \qquad BP_t = int_L L_{t-1} - int_D D_{t-1} - int_A A_{t-1} \qquad \Delta A_t = \Delta HPM_t + CBP_t$$

~~TP~~
~~BP~~
~~CBP~~
~~D~~
~~A~~
~~L~~
~~DP~~
W
C
RP
I
e
p_e
HPM

2. Steps in developing an SFC model (example)

Step 4: Identify the variables that need to be determined based on behavioural equations. Select your behavioural equations.

For example, consumption expenditures: $C_t=c_1Y_{Dt-1}+c_2V_{Ht-1}$

Step 5: Put together the identities and the behavioural equations.

2. Steps in developing an SFC model

- **Income distribution**: Zezza (2008), van Treeck (2009), Dafermos and Papatheodorou (2015), Kapeller et al. (2017)
- **Credit rationing/liquidity preference**: Chatelain (2010), Dafermos (2012), Le Heron and Mouakil (2008)
- **Shadow banking**: Eatwell et al. (2008), Lavoie (2014), Nikolaidi (2015), Botta et al. (2018, 2019)
- **Minskyan analyses**: Nikolaidi (2014b), Keen (2013), Passarella (2012), Ryoo (2010), Taylor (2004, ch. 9), Tymoigne (2009, ch. 5), Dafermos (2018)
- **Open economy issues**: Bortz (2014), Greenwood-Nimmo (2014), Lavoie and Daigle (2011), Lavoie and Zhao (2009), Mazier and Valdecantos (2019), Carnevali et al. (2019)

3. Incorporating ecological aspects into SFC models

- Traditional SFC models are not in line with **ecological macroeconomics**.
- They ignore the fact that production and consumption are not possible without using **energy** and **matter**.
- They do not take into account that economic activity creates various types of **waste** that can destabilise the ecosystem.
- They also neglect other types of **environmental problems**, like the loss of biodiversity, water scarcity and deforestation.

3. Incorporating ecological aspects into SFC models

- One first way to analyse ecological issues in SFC models is by making a distinction between '**green**' and '**conventional**' investment, products and financial instruments (e.g. loans, bonds).
- Moreover, the implications of **degrowth** can be analysed by simulating a reduction in consumption.
- However, a more integrated analysis of ecological issues requires the incorporation of **environmental variables** (like energy, matter and waste) into modelling.
- This permits an integrated examination of the interactions between the ecosystem and the macroeconomy.

3. Incorporating ecological aspects into SFC models

- The **DEFINE** (Dynamic Ecosystem-FINance-Economy) model is a global **SFC ecological macroeconomic model** that analyses the interactions between the macroeconomy, the financial system and the ecosystem (Dafermos, Nikolaidi and Galanis, 2017, 2018; Dafermos and Nikolaidi, 2019, forthcoming).
- The model incorporates both (i) the distinction between green and conventional investment, loans etc. and (ii) an analysis of environmental variables (like energy and matter); the latter draws on the work of **Georgescu-Roegen**.
- For more information, see: www.define-model.org

3. Incorporating ecological aspects into SFC models

The model consists of two big blocks and various sub-blocks.

Ecosystem

- Matter, waste and recycling
- Energy
- Emissions and climate change
- Ecological efficiency and technology

Macroeconomy and financial system

- Output determination
- Firms
- Households
- Banks
- Government sector
- Central banks

3. Incorporating ecological aspects into SFC models

Physical flow matrix

	Material balance	Energy balance
Inputs		
Extracted matter	$+M_t$	
Renewable energy		$+ER_t$
Non-renewable energy	$+CEN_t$	$+EN_t$
Oxygen used for fossil fuel combustion	$+O2_t$	
Outputs		
Industrial CO_2 emissions	$-EMIS_{INt}$	
Waste	$-W_t$	
Dissipated energy		$-ED_t$
Change in socio-economic stock	$-\Delta SES_t$	
Total	0	0

- Material balance: $M_t+CEN_t+O2_t=EMIS_{INt}+W_t+SES_t$
- Energy balance: $ER_t+EN_t=ED_t$

3. Incorporating ecological aspects into SFC models

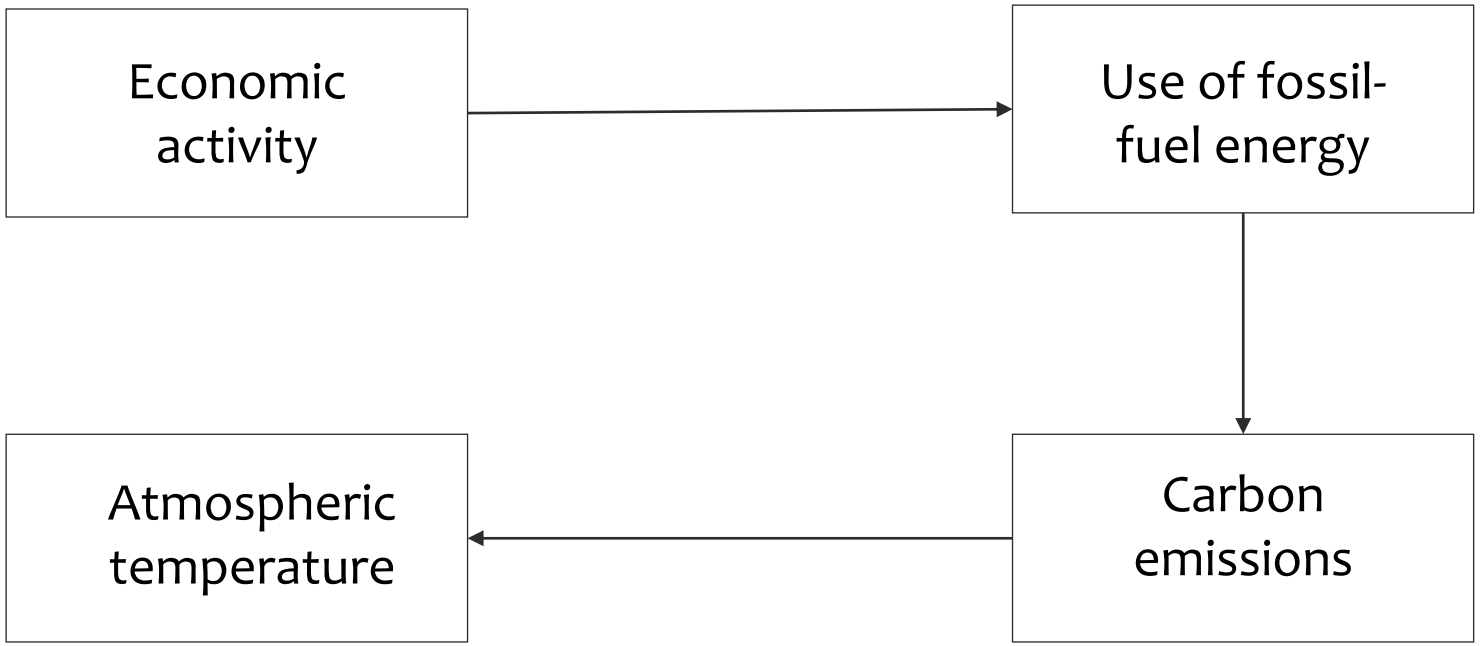
Physical stock-flow matrix

	Material reserves	Non-renewable energy reserves	Cumulative CO_2 emissions	Socio-economic stock	Hazardous waste
Opening stock	REV_{Mt-1}	REV_{Et-1}	$CO2_{CUMt-1}$	SES_{t-1}	HWS_{t-1}
Additions to stock					
Resources converted into reserves	$+CON_{Mt}$	$+CON_{Et}$			
CO_2 emissions			$+EMIS_t$		
Production of material goods				$+MY_t$	
Non-recyded hazardous waste					$+\tilde{haz}W_t$
Reductions of stock					
Extraction/use of matter or energy	$-M_t$	$-EN_t$			
Demolished/disposed socio-economic stock				$-DEM_t$	
Closing stock	REV_{Mt}	REV_{Et}	$CO2_{CUMt}$	SES_t	HWS_t

- Material reserves: $REV_{Mt-1}+CON_{Mt}-M_t=REV_{Mt}$
- Non-renewable energy reserves: $REV_{Et-1}+CON_{Et}-EN_t=REV_{Et}$
- Cumulative CO_2 emissions: $CO2_{CUMt-1}+EMIS_t=CO2_{CUMt}$
- Socio-economic stock: $SES_{t-1}+MY_t-DEM_t=SES_t$
- Hazardous waste: $HWS_{t-1}+hazW_t=HWS_t$

3. Incorporating ecological aspects into SFC models

The effects of economic activity on climate change



3. Incorporating ecological aspects into SFC models

Feedback effects of climate change on economic activity

Type of shock		From gradual global warming	From extreme weather events
Demand	Investment	Uncertainty about future demand and climate risks	Uncertainty about climate risks
	Consumption	Changes in consumption patterns, e.g. more savings for hard times	Increased risk of flooding to residential property
	Trade	Changes in trade patterns due to changes in transport systems and economic activity	Disruption to import/export flows due to extreme weather events
Supply	Labour supply	Loss of hours worked due to extreme heat. Labour supply shock from migration	Loss of hours worked due to natural disasters, or mortality in an extreme case. Labour supply shock from migration
	Energy, food and other inputs	Decrease in agricultural productivity	Food and other input shortages
	Capital stock	Diversion of resources from productive investment to adaptation capital	Damage due to extreme weather
	Technology	Diversion of resources from innovation to adaptation capital	Diversion of resources from innovation to reconstruction and replacement

Source: NGFS (2019)

Question: According to your view, which of these effects is more important for the Global South?

3. Incorporating ecological aspects into SFC models

- In modelling, the feedback effects of the environment on the economy can be incorporated through **damage functions**.
- In **mainstream environmental models** the damages are confined to the supply side and tend to be optimistic.
- In **DEFINE** damages refer both to the demand- and the supply-side and are more pessimistic.
- The incorporation of damages remains a very challenging task and we are still far from formulating them properly.

3. Incorporating ecological aspects into SFC models

Policies that can be analysed in DEFINE:

- **Green fiscal policies:** Carbon taxes, green subsidies, green public investment
- **Green monetary/financial policies:** Green differentiated capital requirements, green quantitative easing
- **Degrowth policies/strategies:** Reduction in consumption, reduction of working hours

3. Incorporating ecological aspects into SFC models

Ecological SFC models

- **Climate finance**: Dafermos et al. (2017, 2018), Bovari et al. (2018), Lamperti et al. (2018) Dunz et al. (forthcoming), Dafermos and Nikolaidi (forthcoming)
- **Green fiscal policy**: Naqvi and Stockhammer (2018), Monasterolo and Raberto (2019), Dafermos and Nikolaidi (2019)
- **Degrowth**: Jackson and Victor (2015), Richters and Siemoneit (2017), DAlessandro et al. (2018), Monserand (2019)

4. Conclusion

- SFC models constitute a flexible tool for analysing complex issues that involve an active role of **finance**.
- More **progress** needs to be made in the way that these models are calibrated, validated and simulated.
- There is still only a small number of **country-specific** models (especially for the Global South).
- Many important **ecological aspects** have not yet been incorporated into SFC models (e.g. biodiversity, water scarcity).
- The **distributional aspects** of environmental policies have only partially been investigated.
- **Intersecting inequalities** have not been analysed.
- The role of **power** is basically taken into account only as an exogenous factor.