Introduction to SFC Dynamic Models

Lecture A Foundations of SFC Models for Economic Research

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https://github.com/marcoverpas/Six_lectures_on_sfc_models

Lecture schedule

A. **Foundations of SFC Models for Economic Research**
   1. **The State of Macroeconomics**
   2. **The Inception of SFC models**
   3. **SFC Accounting Principles**
   4. **SFC Equations and Coding**

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

F. Empirical SFC Models (using *Bimets*)

1 The State of Macroeconomics

Issues with standard models

Increasing dissatisfaction with DSGE models (Blanchard, Krugman, Mankiw, Romer, Solow, Wren-Lewis, etc.)

Three main weaknesses:

a) Unrealistic assumptions ► full rationality, optimising behaviour, etc.

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b) Limited range ► no financial markets, no banks, no social classes, poor ecosystem

c) Poor data fit ► outclassed by other models in the S/R, trivial results in the M/R (long-lasting crises are ruled out)

Countermand!

(c) Poor data fit

(a) Unrealistic assumptions

model and an explicit role for forward-looking expectations. A weakness of DSGE models is that they often do not fit the data as well as other models, and the causal mechanisms do not always correspond to how economists and policymakers think the economy really works. In order to more easily manage these models, they typically focus on only a few key variables, which can limit the range of situations where they are useful.

(b) Limited range

The key strength of full-system econometric models like MARTIN is that they are flexible enough to incorporate the causal mechanisms that policymakers believe are important and fit the observable relationships in the data reasonably well. They can also be applied very broadly to model a wide range of variables. This flexibility reflects that the model is not derived from a single theoretical framework, which can make causal mechanisms less clear than in DSGE models. The model might capture an empirical relationship that exists in the data, but the cause of this might not be well understood. This means that developments may be more difficult to interpret and assumptions may need to be made about the mechanisms that are at work. If the true causal mechanisms are

Excerpt from *Reserve Bank of Australia*, March 2018 Bulletin

Is there an alternative?

- Alternative models:
  a) CGE models (broader scope, but based on the same assumptions of DSGE models)
  b) Leontief IO models (broader scope, but not much room for dynamics and finance)
  c) Heterogeneous agent-based models, network analysis, and other complexity models
  d) Rediscovery of traditional macroeconometric models
  e) Theoretical and empirical SFC models (Zezza and Zezza 2019, Carnevali et al. 2019)
- The Bank of England (2016) and the Italian Ministry of Economy and Finance (2022) have developed their own empirical SFC models.
- Other intitutions (e.g. OECD) and world-leading economists (e.g. Simon Wray-Lewis vs Martin Wolf) have shown interest in SFC models.
- Researchers at the Bank of Italy have released a new *R* package, named *Bimets*, for the analysis of time series and macroeconometric modelling, which can be used for SFCMs.

2 The Inception of SFC Models

The origin of SFC models

SFC models gained popularity after Wynne Godley used them to predict the US crises in both 2001 and 2007:

> *There could be a further year or more of robust expansion … [but] current growth is associated with seven unsustainable processes* (Godley 1999)

Godley and the *Cambridge Economic Policy Group* built upon the works of:

- Morris Copeland (1949): integrated national income identities with flow of funds through the quadruple accounting principle
- James Tobin (1981,1982) and the *Yale Group*: Keynesian theory of portfolio equations (as functions of expected return rates and liquidity preference)

Since the the late 2000s, SFC models have emerged as a prevalent method or language among non-neoclassical macroeconomic modellers.

Integrating finance and production

In 2007 Godley and Lavoie published what is still today the reference manual for SFC modelling: Monetary Economics: An Integrated Approach to Credit, Money, Income, Production and Wealth.

Nine SFC models are presented and simulated, in which money is endogenous and behavioural equations respond to post-Keynesian precepts.

Dos Santos (2006) named this method the stock-flow consistent (SFC) approach to macroeconomics (but accounting consistency should be a requirement for all models).

SFC models are well-known outside economics. Ecological economists and environmental scientists use them to assess the impact of anthropic activities on the ecosystem.

Economic SFC models integrate the financial and the real side of the economy, thus tracking stock-flow ratios and identifying un-sustainable processes (e.g. a growing debt/income ratio).

Links with other disciplines

SFCMs can be regarded system dynamics models, which analyse the behaviour of a (complex) system over time, tracking flows & stocks and using feedback loops & time delays.

Ecological economists and physicists have developed SFC models that resemble the models popularised by Godley and Lavoie (2007) and other Keynesian economists.

Basic SFC models have been expanded and/or cross-bred with other models:

- Open-Economy or Multi-Area SFC models ► **MA-SFC** IO Model
- Ecological SFC models ► **ECO-SFC**
- Heterogenous Agent-Based SFC models ► **AB-SFC**
- Input-Output SFC models ► **IO-SFC**
- Empirical SFC models ► **E-SFC** (data-to-theory, theory-to-data)

3 SFC Accounting Principles

Basic principles

SFC models are based on national accounts and flow of funds. They are explicitly designed to meet **four accounting principles**:

a) Flow consistency ▶ every transaction comes from somewhere and goes to somewhere

b) Stock consistency ▶ a liability issued by agent or sector A is held as a financial asset by agent or sector B

c) Stock-flow consistency ▶ flows affect stocks, capital gains (losses) must be recorded

d) Quadruple book-keeping ▶ every transaction entails four different entries:

- An outflow (e.g. a household purchases an item)
- An inflow (e.g. a firm sales the item)
- A reduction in assets or an increase in liabilities (e.g. household's cash and/or deposits reduce)
- An increase in assets or a reduction in liabilities (e.g. firm's cash and or deposits increase)

Accounting matrices

The economy is divided into several sectors (e.g., households, non-financial firms, commercial banks, central bank, government, and the foreign sector).

SFC models are made up of two components: accounting matrices and dynamic equations.

Accounting matrices match the System of National Accounts:

- The balance sheet (BS) displays tangible stocks (fixed capital, housing), financial assets, and financial liabilities of each macro-sector.
- The transactions-flow matrix (TFM) shows financial flows associated with stocks and sectoral budget constraints. It combines the national income equations (identities) with sectoral flow-of-funds accounting.

The full-integration matrix integrates the TFM and the BS. It shows that the change in net assets arises from both transactions (Δ in quantities) and revaluation effects (Δ in prices).

The balance sheet

Assets and liabilities (stocks)

Economic sectors or agents

	Households	Firms	Banks	Central Bank	Government	…	Σ
Cash	$+H_h$			$-H_s$		…	0
Deposits	$+M_h$		$-M_s$			…	0
Loans		$-L_f$	$+L_s$			…	0
Bills	$+B_h$			$+B_{cb}$	$-B_s$	…	0
Capital		$+K$				…	$+K$
…	…	…			…	…	0
Balance (net worth)	$-V_h$	0	0	0	$+V_g$	…	$-\Sigma V$
Σ	0	0	0	0	0	0	0

Consistency across sectors

Accumulation of fixed capital

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

Consistency within sectors

The transactions-flow matrix

Transactions and Δ in stocks

Capital account

	Households	Firms		Banks	Central Bank	Government	…	Σ
		Current	Capital					
Consumption	$-C$	$+C$					…	0
Investment		$+I$	$-I$				…	0
Wages	$+WB$	$-WB$						0
Interests on loans		$-r_{l,-1} \cdot L_{f,-1}$		$+r_{l,-1} \cdot L_{s,-1}$			…	0
…	…	…	…	…	…	…	…	0
Δ in cash	$-\Delta H_h$				$+\Delta H_s$		…	0
Δ in loans			$+\Delta L_f$	$-\Delta L_s$			…	0
…	…	…	…	…				0
Σ	0	0	0	0	0	0	0	0

Column = budget constraint

Reverse sign

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

The full-integration matrix

When prices of assets are included, a full-integration matrix is also necessary, as:

$$Stock_t = Stock_{t-1} + Flow_t + Capital\ gain_t$$

As an example, let's consider firms' equities and fixed capital:

		Households	Firms	Other	Σ
	Net worth, end of $t-1$	$V_{h,t-1}$	$V_{f,t-1}$	...	K_{t-1}
Change in net assets arising from transactions	Change in equities	$+\Delta e_h \cdot p_{e,t}$	$-\Delta e_s \cdot p_{e,t}$	...	0
	Change in fixed capital		$+\Delta k \cdot p_{k,t}$	...	$+\Delta k \cdot p_{k,t}$
Change in net assets arising from revaluations	Capital gains in equities	$+\Delta p_e \cdot e_{h,t-1}$	$-\Delta p_e \cdot e_{s,t-1}$	...	0
	Capital gains in fixed capital		$+\Delta p_k \cdot k_{t-1}$	...	$+\Delta p_k \cdot k_{t-1}$
	Net worth, end of t	$V_{h,t}$	$V_{f,t}$	...	K_t

4 SFC Equations and Coding

Identities and behavioural equations

BS and TFM allow deriving the first set of model equations, namely accounting identities.

Identities are then coupled with equilibrium conditions and behavioural equations to close the model:

- Identity: accounting definition, which is always true. Example: $Y \equiv C + I + G + X - M$
- Equilibrium condition: adjustment mechanism that matches demand with supply
  Example: $M_s = M_d$
- Behavioural (or stochastic) equation: defines the behaviour of a certain variable
  Example: $C = \alpha_1 \cdot YD^e + \alpha_2 \cdot V_{-1}$

Behavioural equations are usually based on the assumption that economic agents set stock-flow norms or targets, e.g. wealth-to-income ratio: $\frac{V}{YD} = \frac{1-\alpha_1}{\alpha_2}$.

Tobin's portfolio equations

- One of the key behavioural assumptions is that households make a two stage decision:
  i. they decide how much they consume/save out of their income
  ii. 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:

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

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

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

Portfolio vertical constraints

- In matrix form:

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

$\Sigma = 1$ $\Sigma = 0$ $\Sigma = 0$

- 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.

Other portfolio constraints

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

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

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:

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

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.

Theory and policy implications

The medium-run dynamics of SFC models is usually not predetermined by a supply-side exogenous attractor (e.g. NAIRU). It is constrained by the accounting structure.

While Godley was quite confident about the constraining power of an accurate accounting, the medium-run dynamics of SFC models is defined also by behavioural assumptions.

SFC modellers usually assume that production, income and employment are demand-led both in the short- and long-run. Agents do not maximise. They follow stock-flow norms.

Some heterodox policy corollaries follow (e.g. fiscal policies can imply long-lasting effects, monetary policies can bring about paradoxical and counter-intuitive effects, etc.).

However, there is flexibility. In principle, SFC models are consistent with a variety of theoretical views.

Supply-side ecological constraints are increasingly incorporated into the models.

Solution and identification

Standard SFC models are medium-scale macro-econometric dynamic models (≈ 30 to 250 equations). But they can be meso- (IO-SFC) or micro-founded (AB-SFC).

Usually formulated in discrete time (difference equations), but they can also be developed in continuous time (differential equations).

The simplest models can be solved analytically by finding steady-state solutions. More advanced models must be solved through computer simulations.

Coefficients can be:

a) fine-tuned to obtain a specific baseline scenario (previous studies, selected from a reasonable range of values)

b) calibrated to match / replicate the data

c) estimated from observed data (using econometric methods: OLS, cointegration, etc.)

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

SFC Coding

- Unlike Dynare (a MATLAB add-on package) for DSGE models, there is no program used by all SFC modellers.
- The codes used in Godley and Lavoie (2007) were originally developed by Gennaro Zezza using EViews (and Excel).
- R (RStudio) has become increasingly popular over time, because of its flexibility, and it is currently the most used programming environment in SFC modelling.
- There are currently some dedicated packages in *R*, notably SFCR and Godley. Besides, Bimets can be used for developing empirical SFC models.
- MATLAB (with or without Dynare), Mathematica, Python and Julia can be employed as well, especially for creating continuous-time and agent-based SFC models.
- Another option is a software package named Minsky (developed by Steve Keen) that allows visually modelling macroeconomic system dynamics.

Program options

		Coverage				Time	Ease	Dissemination	Cost
		Numerical SFC	Empirical SFC	Agent-based SFC	Input-output SFC				
EViews		Yes	Yes	No	Yes, but...	Discrete	Medium/High	High	Not free
R	No ded. package	Yes	Yes, but...	Yes, but...	Yes	Discrete	Medium	High	Free
	SFCR	Yes	No	No	No	Discrete	Medium/High	High	Free
	Godley	Yes	No	No	No	Discrete	High	Low	Free
	Bimets	Yes, but...	Yes	No	Yes, but...	Discrete	Medium	Low	Free
Python		Yes	Yes, but...	Yes	Yes	Discrete	Medium/Low	Medium	Free
Julia		Yes	Yes, but...	Yes	Yes	Discrete/Continuous	Medium	Low	Free
Matlab	No ded. package	Yes	Yes, but...	Yes	Yes	Discrete/Continuous	Medium	Medium	Not free
	Dynare	Yes	Yes	No	Yes but...	Discrete	High	High, but...	Free, but...
Mathematica		Yes	No	Yes, but...	Yes, but...	Continuous	Medium/Low	Low	Not free
Minsky		Yes	No	No	Yes, but...	Continuous	Medium	Medium	Free
Excel		Yes	No	No	Yes, but...	Discrete	High	Medium	Almost free

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) Copy and paste the code in the main *R* field (top-left)

g) Run the code by clicking Source

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

i) Charts are displayed in the Plots field (bottom-right)

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, pp. 223-276.

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Thanks

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