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ReTraCE

Realising the Transition towards the Circular Economy

SFC Models: An Introduction

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PART A

THEORY AND METHOD

The State of Macro 1/2

- Increasing dissatisfaction with standard (DSGE) macro models (Blanchard, Krugman, Mankiw, Romer, Solow, Wren-Lewis, etc.)
- Three main weaknesses:
  - Internal consistency issues (production function, utility/preferences, etc.)
  - Unrealistic assumptions (full rationality) and irrelevance (e.g. no financial markets, no banks, no classes, no interaction with ecosystem, etc.)
  - Poor data fit, outclassed by other models in the S/R
- Useless for L/R forecasts: crises are ruled out!

The State of Macro 2/2

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.

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, Bulletin, March 2018

SFC Models: Inception and Features 1/3

- Someone saw it coming (Godley 1999)!
- Godley and the Cambridge Economic Policy Group built upon the works of:
  - Copeland (1949): integrates NIIs with FoFs through the quadruple accounting principle
  - Tobin (1981,1982) and the Yale Group: Keynesian theory and portfolio equations (expected relative return rates and liquidity preference)

SFC Models: Inception and Features 2/3

- Godley and Lavoie (2007) incorporated these principles into a monetary production economy where the supply of money is endogenous and behavioural equations respond to Kaleckian or Keynesian precepts
- Dos Santos (2006) named it the stock-flow consistent (SFC) approach to macro modelling
- To model complex interactions between the financial and the real spheres of a financially-sophisticated capitalist economy

SFC Models: Inception and Features 3/3

Four accounting principles:

- Flow consistency: every transaction comes from / go to somewhere
- Stock consistency: a liability issued by A is held as a financial asset by B
- SF consistency: flows affect stocks (do not miss capital gains/losses)
- Quadruple book-keeping: every transaction entails four different entries (outflow, inflow, two complementary changes in assets/liabilities)

SFC Accounting Matrices 1/3

These principles are incorporated in:

- Balance Sheet (BS): displaying sectoral tangible and financial stocks and liabilities of each macro-sector (households, firms, banks, central bank, government, foreign sector)
- Transactions-Flow Matrix (TFM): showing financial flows associated with stocks and sectoral budget constraints. It combines the NI equation with sectoral FoF accounting

SFC Accounting Matrices 2/3

- BS and TFM allow deriving the first set of model equations, namely accounting identities
- Identities are then coupled with equilibrium conditions and dynamic stochastic (or behavioural) equations to close the model
- No utility maximisation. Agents have stock-flow targets instead (wealth-to-income ratio, debt-to-income ratio, etc.)

SFC Accounting Matrices 3/3

Steps in developing a SFC model (see Dafermos website)

1. Create BS
2. Create TFM
3. Write down identities from the TFM
   - Use columns to derive budget constraints
   - Use also rows with multiple entries
   - Identify buffer variables
4. Define behavioural equations

Model Calibration and Simulations 1/3

- SFCMs long-run dynamics is not constrained by any supply-side exogenous attractor (e.g. NRU). It is affected by their accounting structure
- Production and employment are (usually) demand-led both in the short- and long-run
- Corollary: fiscal policies have long-lasting effects. They are more effective than monetary policies. Paradoxes and counterintuitive effects are possible (see Model PC below)

Model Calibration and Simulations 2/3

- SFCMs are medium-scale structural macro-econometric dynamic models. But they can be meso- (IO-SFC) or micro-founded (AB-SFC)
- Usually solved through computer simulations. Coefficients can be:
  - estimated using observed data (econometrics)
  - calibrated based on previous studies or selected from a reasonable range of values
  - fine-tuned to match the data or to obtain a specific baseline scenario

Model Calibration and Simulations 3/3

Steps in simulating a SFC model (see Dafermos website)

1. Run the model
2. Validate results through auto- and cross-correlation analysis of key variables under the baseline
3. Check robustness of findings through sensitivity tests (changing key parameters)
4. Shock key coefficients to obtain alternative scenarios
5. Compare alternative scenarios with baseline results (comparative dynamics)

Notes: points 2 and 3 are for advanced analyses only

Two Simple Models: MODEL PC 1/6

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

Two Simple Models: MODEL PC 2/6

Table 4.1 Balance sheet of Model *PC*

	Households	Production	Government	Central Bank	Σ
Money	$+H$			$-H$	0
Bills	$+B_h$		$-B$	$+B_{cb}$	0
Balance (net worth)	$-V$		$+V$		0
Σ	0		0	0	0

Notes: Tables 4.1, 4.2, 7.1 and 7.2 are taken from Godley and Lavoie (2007). A '+' before a magnitude denotes an asset, whereas '–' denotes a liability (except for the Balance entry, where signs are reversed)

Two Simple Models: MODEL PC 3/6

Table 4.2 Transactions-flow matrix of Model *PC*

	Households	Production	Government	Central bank: Current	Central bank: Capital	Σ
Consumption	$-C$	$+C$				0
Government expenditures		$+G$	$-G$			0
Income = GDP	$+Y$	$-Y$				0
Interest payments	$+r_{-1} \cdot B_{h-1}$		$-r_{-1} \cdot B_{-1}$	$+r_{-1} \cdot B_{cb-1}$		0
Central bank profits			$+r_{-1} \cdot B_{cb-1}$	$-r_{-1} \cdot B_{cb-1}$		0
Taxes	$-T$		$+T$			0
Change in money	$-\Delta H$				$+\Delta H$	0
Change in bills	$-\Delta B_h$		$+\Delta B$		$-\Delta B_{cb}$	0
Σ	0	0	0	0	0	0

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

Two Simple Models: MODEL PC 4/6

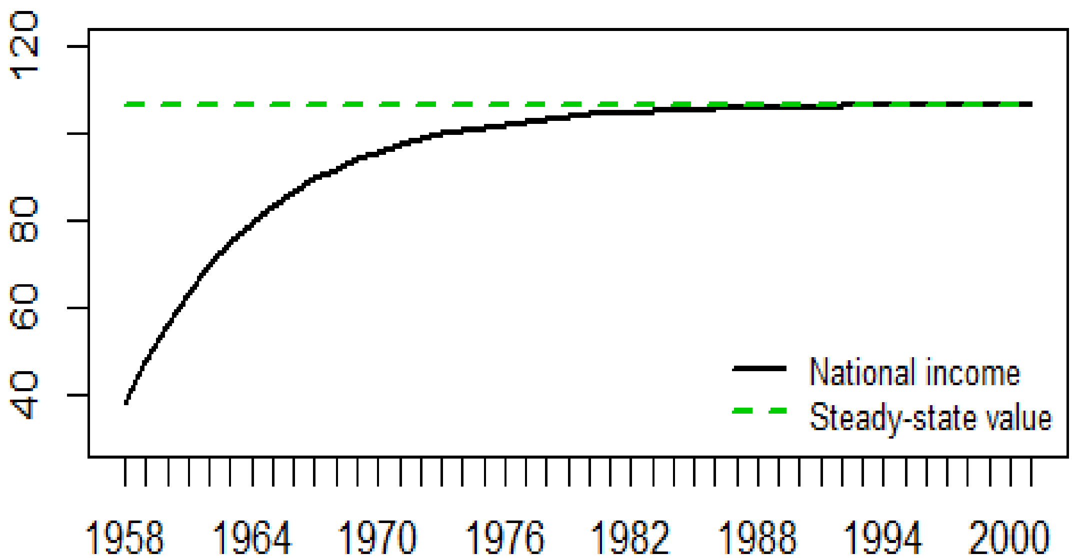
Model PC equations

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:	$V = V_{-1} + YD - C$	(4)
Consumption:	$C = \alpha_1 \cdot YD + \alpha_2 \cdot V_{-1}$	(5)
Cash held by households:	$H_h = V - B_h$	(6)
Bills held by households:	$B_h = \lambda_0 \cdot V + \lambda_1 \cdot V \cdot r - \lambda_2 \cdot YD$	(7)
Cash held by households:	$H_h = (1 - \lambda_0) \cdot V - \lambda_1 \cdot V \cdot r + \lambda_2 \cdot YD$	(6A)
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:	$H_h = H_s$	

Two Simple Models: MODEL PC 5/6

Stationary (or quasi steady-state) solution:

$$Y^* = \frac{G + r \cdot B_h^* \cdot (1-\theta)}{\theta}$$



$G = 20$
$r = 0.025$
$\theta = 0.2$
$B_h^* \sim 64.86$

$Y^* \sim 106.49$

Two Simple Models: MODEL PC 6/6

Figure 4.3: Evolution of shares of bills and money balances in the portfolio of households, following an increase in 100 points in the rate of interest on bills

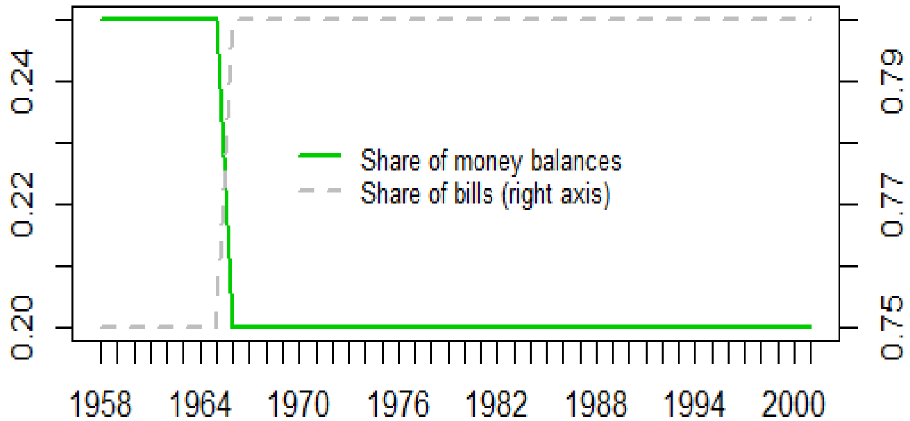
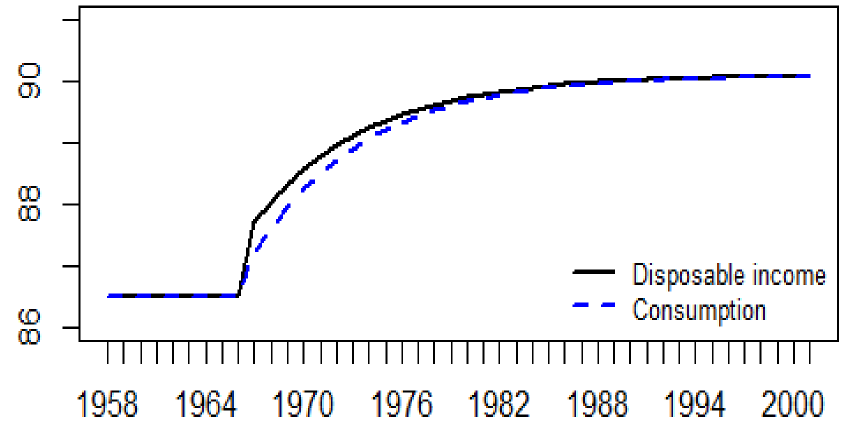


Figure 4.4: Evolution of household disposable income and household consumption following an increase in 100 points in the rate of interest on bills



Two Simple Models: MODEL BMW 1/8

- Closed economy
- Three agents: households, firms, banks
- A/L: loans, deposits, tangible (or fixed) capital
- Investment funded by loans and internal funds
- Target capital to output ratio
- Zero net profits
- No State, no outside money (cash)
- No ecosystem

Two Simple Models: MODEL BMW

Table 7.1 Balance sheet of Model *BMW*

	Households	Production firms	Banks	Σ
Money deposits	$+M$		$-M$	0
Loans		$-L$	$+L$	0
Fixed capital		$+K$		$+K$
Balance (net worth)	$-V_{\mathrm{h}}$	0	0	$-V_{\mathrm{h}}$
Σ	0	0	0	0

Two Simple Models: MODEL BMW 3/8

Table 7.2 The accounting transactions-flow matrix of Model *BMW*

	Households	Production firms: Current	Production firms: Capital	Banks: Current	Banks: Capital	Σ
Consumption	$-C$	$+C$				0
Investment		$+I$	$-I$			0
[*Production*]		$[Y]$				
Wages	$+WB$	$-WB$				0
Depreciation allowances		$-AF$	$+AF$			0
Interest on loans		$-r_{l-1} \cdot L_{-1}$		$+r_{l-1} \cdot L_{-1}$		0
Interest on deposits	$+r_{m-1} \cdot M_{-1}$			$-r_{m-1} \cdot M_{-1}$		0
Change in loans			$+\Delta L$		$-\Delta L$	0
Change in deposits	$-\Delta M$				$+\Delta M$	0
Σ	0	0	0	0	0	0

Two Simple Models: MODEL BMW 4/8

Model BMW equations

Supply of consumption goods:	$C_s = C_d$	(1)
Supply of investment goods:	$I_s = I_d$	(2)
Labour supply:	$N_s = N_d$	(3)
Supply of loans:	$L_s = L_{s,-1} + \Delta L_d$	(4)
Total gross production:	$Y = C_s + I_s$	(5)
Wage bill (as residual income):	$WB_d = Y - r_{l,-1} \cdot L_{d,-1} - AF$	(6)
Amortisation funds:	$AF = \delta \cdot K_{-1}$	(7)
Demand for loans:	$L_d = L_{d,-1} + I_d - AF$	(8)
Disposable income:	$YD = WB_s + r_{m,-1} \cdot M_{d,-1}$	(9)
Deposits held by households:	$M_h = M_{h,-1} + YD - C$	(10)
Supply of deposits:	$M_s = M_{s,-1} + \Delta L_s$	(11)

Two Simple Models: MODEL BMW 5/8

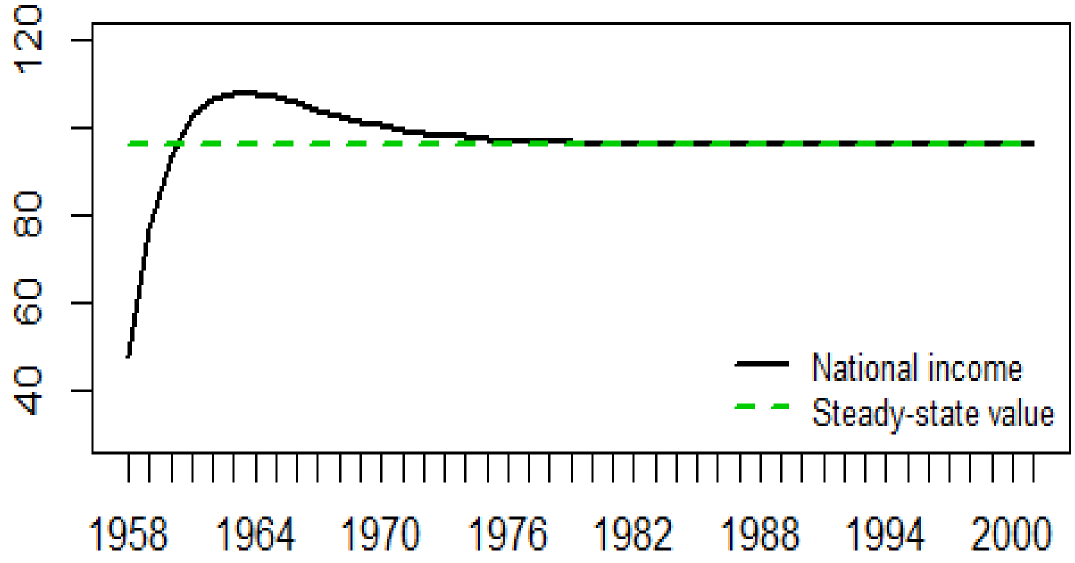
Model BMW equations (cont'd)

Return rate on deposits:	$r_m = r_l$	(12)
Wage bill:	$WB_s = w \cdot N_s$	(13)
Demand for labour:	$N_d = \frac{Y}{pr}$	(14)
Wage rate:	$w = \frac{WB_d}{N_d}$	(15)
Consumption:	$C_d = \alpha_0 + \alpha_1 \cdot YD + \alpha_2 \cdot M_{h,-1}$	(16)
Capital stock:	$K = K_{-1} + I_d - DA$	(17)
Depreciation allowances:	$DA = \delta \cdot K_{-1}$	(18)
Target capital stock:	$K^T = \kappa \cdot Y_{-1}$	(19)
Gross investment:	$I_d = \gamma \cdot (K^T - K_{-1}) + DA$	(20)
Interest rate on loans:	$r_l = \bar{r}_l$	(21)
Redundant equation:	$M_h = M_s$	

Two Simple Models: MODEL BMW 6/8

Stationary (steady-state) solution:

$$Y^* = \frac{\alpha_0}{(1-\alpha_1)\cdot(1-\delta\cdot\kappa) - \alpha_2\cdot\kappa}$$



$\alpha_0 = 12$
$\alpha_1 = 0.75$
$\delta = 0.15$
$\kappa = 1$

$Y^* = 96$

Two Simple Models: MODEL BMW 7/8

Figure 7.1: Evolution of household disposable income and consumption, following an increase in autonomous consumption expenditures

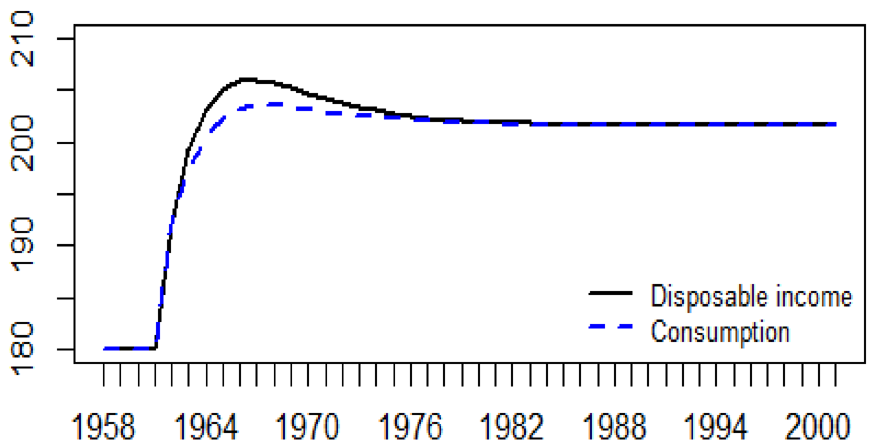
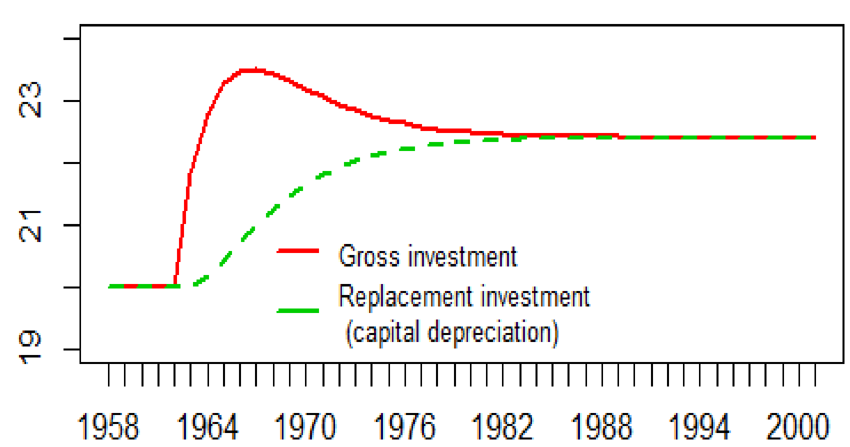


Figure 7.2: Evolution of gross investment and disposable investment, following an increase in autonomous consumption expenditures



Two Simple Models: MODEL BMW 8/8

Figure 7.3: Evolution of household disposable income and consumption, following an increase in the propensity to save out of disposable income

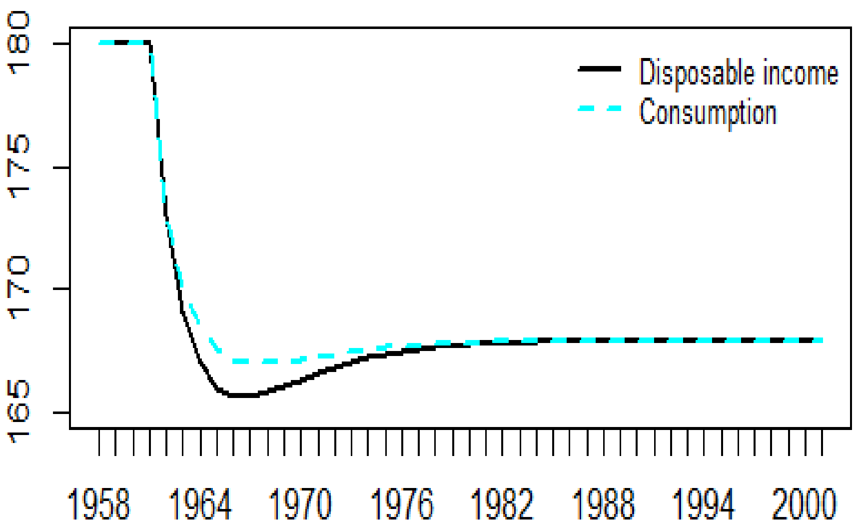
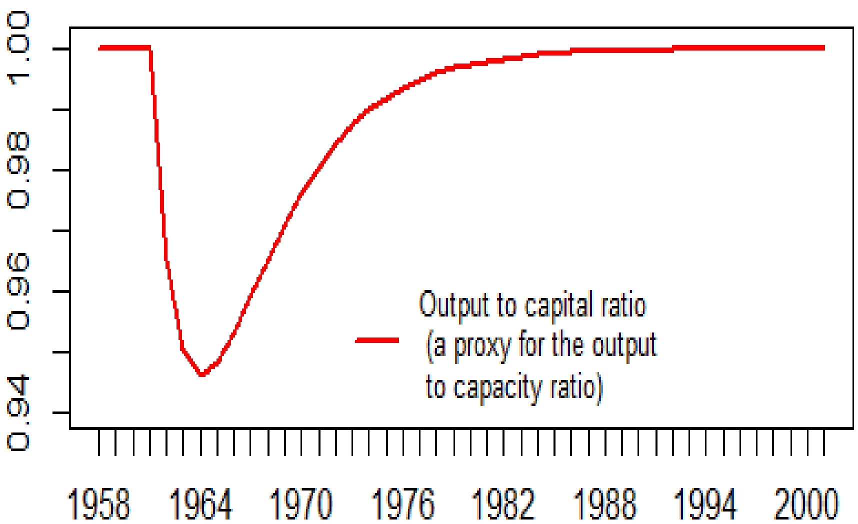


Figure 7.4: Evolution of the output to capital ratio following an increase in the propensity to save out of disposable income



Adding the Ecosystem 1/4

Physical stock-flow matrix and physical flow matrix (Dafermos et al. 2017)

(*a*)

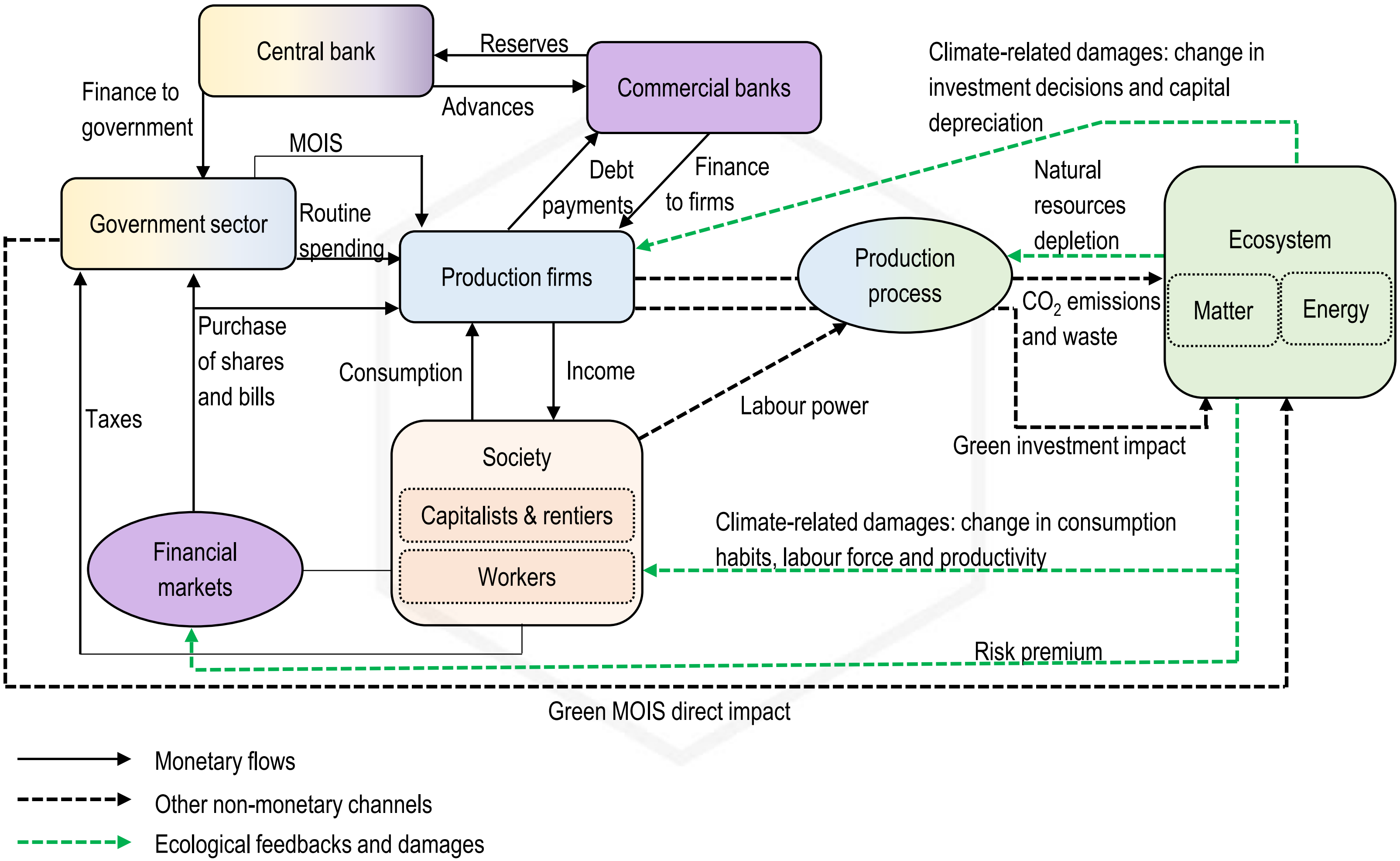
	Material reserves	Energy reserves	Atmospheric CO_2 concentrat.	Socio-economic stock	Hazardous waste
Initial stock	$K_{m,-1}$	$K_{en,-1}$	$CO2_{AT,-1}$	$K_{se,-1}$	HWS_{-1}
Resources converted into reserves	$+CONV_m$	$+CONV_{en}$			
CO_2 emissions (global)			$+EMIS$		
Production of material goods				$+Y_{mat}$	
Non-recycled hazardous waste					$+haz \cdot WA$
Extraction/use of matter/energy	$-MAT$	$-EN$			
Net transfer to oceans/biosphere			$+(\phi_{11}-1) \cdot CO2_{AT,-1} + \phi_{21} \cdot CO2_{UP,-1}$		
Demolition of socio-economic stock				$-DES$	
Final stock	K_m	K_{en}	$CO2_{AT}$	K_{se}	HWS

(*b*)

	Material balance	Energy balance
Inputs		
Extracted matter	$+MAT$	
Renewable energy		$+ER$
Non-renewable energy	$+CEN$	$+EN$
Oxygen	$+O2$	
Outputs		
Industrial emissions	$-EMIS_{in}$	
Waste	$-WA$	
Dissipated energy		$-ED$
Change in s.e.s.	$-\Delta K_{se}$	
Σ	0	0

Notes: Matter is measured in Gt while energy is measured in EJ. In sub-table (*a*), a '+' sign denotes additions to the opening stock, whereas '–' denotes reductions; in sub-table (*b*), a '+' sign denotes inputs in the socio-economic system, whereas '–' denotes outputs.

Adding the Ecosystem 2/4



Notes: figure taken from Carnevali et al. (2019).

Adding the Ecosystem (to PC) 3/4

Figure E.2: Temperature following an increase in 100 points in the rate of interest on bills (difference with baseline)

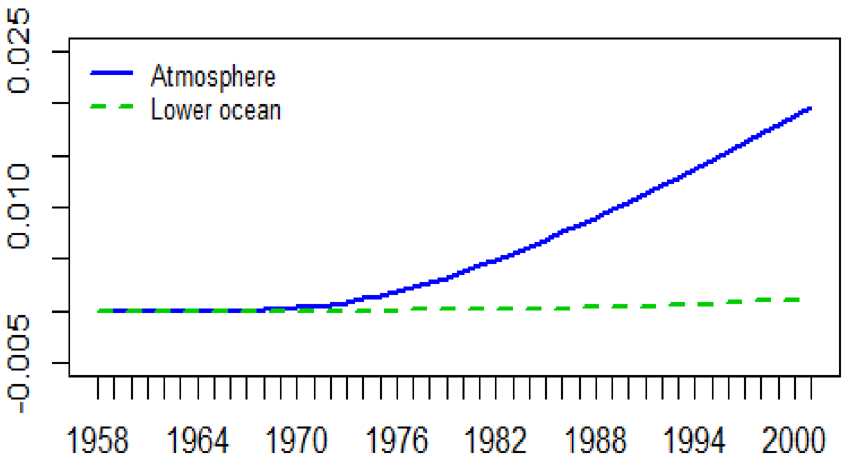
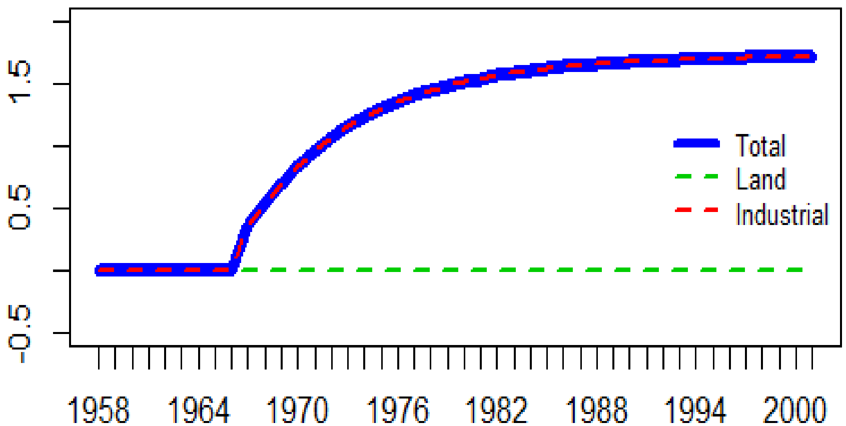


Figure E.1: CO2 annual emissions following an increase in 100 points in the rate of interest on bills (difference with baseline value)



Adding the Ecosystem (to PC) 4/4

Figure E.4: potential output following an increase in 100 points in the rate of interest on bills (difference with baseline)

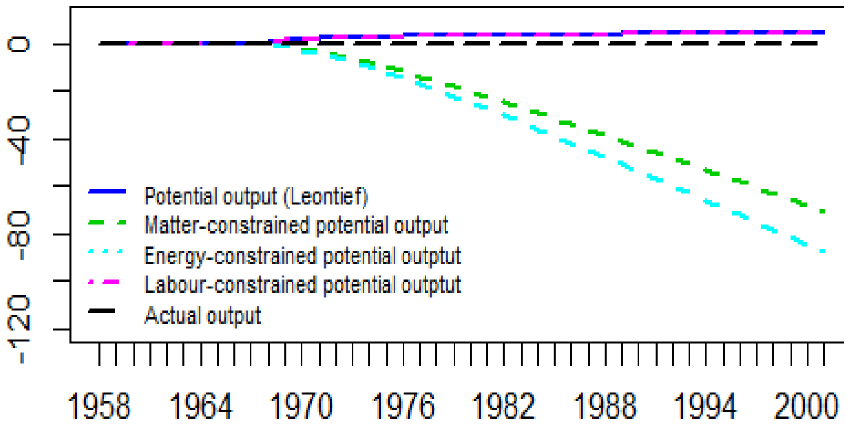
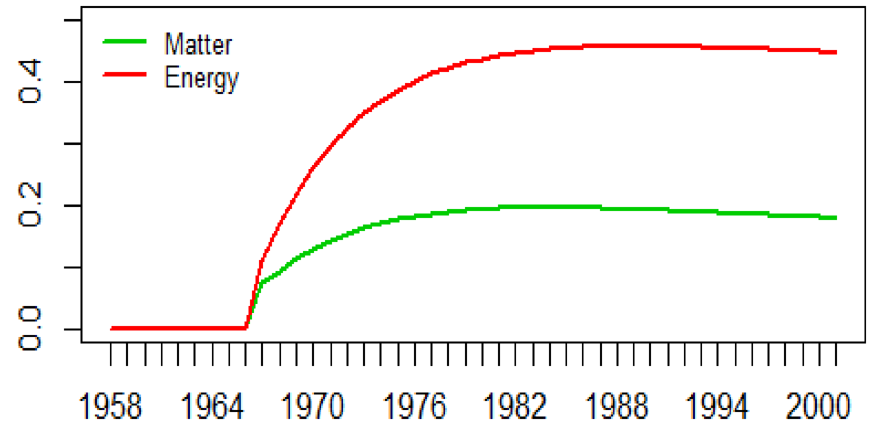


Figure E.3: Depletion rates following an increase in 100 points in the rate of interest on bills (difference with baseline x 1000)



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WEB RESOURCES

http://sfc-models.net/people/gennaro-zezza/

https://yannisdafermos.com/sfc-modelling/

http://www.antoinegodin.eu/

https://www.marcopassarella.it/en/teaching-2/

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PART B

R LABORATORY

Tips

a) Download and install ***R*** + ***R-Studio***

b) Download toy models from marxianomics

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

d) If you do not have a laptop, join other attendants and help them with a, b and c

e) Note: save different versions of your models using different names!