Stock-Flow Consistent Dynamic Models: Features, Limitations and Developments

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Introduction

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- **Aim no. 1:** to provide a short survey/recap of **SFC literature**

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- **Aim no. 2:** to outline a taxonomy of **most recent developments**
- **Aim no. 3:** to develop/present an **ecological two-country model** prototype

Origins: phase one

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- Bridge between the two: **Tobin (1981,1982)** and *New Haven School* (Yale)
- Early SFCMs: **Godley** and *Cambridge Economic Policy Group* (e.g. Godley and Cripps 1983; Coutts et al. 1985; Godley and Zezza 1989)

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- **Modern SFCMs** incorporate Copeland' and Tobin's approaches 'into a monetary production economy where the supply of money is endogenous and where behavioural equations respond to Kaleckian or Keynesian precepts rather than neoclassical ones' (Lavoie 2014, p. 264).

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- SFCM as a **general framework** for all heterodox macroeconomics approaches (Post Keynesian, Kaleckian, Evolutionarist, Marxist, etc.)

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  d) **Quadruple book-keeping**: every transaction entails four different entries: outflow, inflow, two *complementary* changes in assets/liabilities

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  b) The TFM combines the **NI equation with sectoral FoF accounting**
- They allow deriving the first set of model equations, namely **accounting identities**, which are coupled with **equilibrium conditions** and dynamic **stochastic (or behavioural) equations** to close the model

Example of balance sheet

	Households		Production firms	Banks & CB	Government	Foreign	Σ
	Workers	Capitalists					
Money	$+H_w$	$+H_\pi$		$-H_s$			0
Deposits	$+D_w$	$+D_\pi$		$-D_s$			0
Loans			$-L_d$	$+L_s$		$-L_{row}$	0
Conventional capital			$+K_c$				$+K_c$
Green capital			$+K_{gr}$				$+K_{gr}$
Shares		$+e_d \cdot p_e$	$-e_s \cdot p_e$				0
Gov. bonds		$+B_d$		$+B_{cb}$	$-B_s$		0
Balance (net worth)	$-NW_w$	$-NW_\pi$	$+NW_f$	0	*+GDEB*	*+ROWDEB*	$-K_f$
Σ	0	0	0	0	0	0	0

Note: A '+' before a magnitude denotes an asset, whereas '–' denotes a liability

Example of transactions-flow matrix

	Workers	Capitalists	Production firms		Banks & CB	Government	Foreign	Σ
			Current	Capital				
Consumption	$-C_w$	$-C_\pi$	$+C_s$					0
Investment in conventional capital			$+I_{c,s}$	$-I_{c,d}$				0
Green investment			$+I_{gr,s}$	$-I_{gr,d}$				0
Gov. routine spending			$+G_{rout}$			$-G_{rout}$		0
Green spending			$+G_{gr}$			$-G_{gr}$		0
Taxes on income	$-T_w$	$-T_\pi$				$+T$		0
Net export			$+NX$				$-NX$	0
Wage bill	$+\omega \cdot Y$		$-\omega \cdot Y$					0
Depreciation allowances (and amortisation funds)			$-DA_c - DA_{gr}$	$+AF$				0
Interest on loans			$-r_{l,-1} \cdot L_{d,-1}$		$+r_{l,-1} \cdot L_{s,-1}$		$-r_{l,-1} \cdot L_{row,-1}$	0
Interest on deposits	$+r_{d,-1} \cdot D_{w,-1}$	$+r_{d,-1} \cdot D_{\pi,-1}$			$-r_{d,-1} \cdot D_{s,-1}$			0
Return on gov. bonds		$+r_{b,-1} \cdot B_{\pi,-1}$				$-r_{b,-1} \cdot B_{d,-1}$		0
Entrepreneurial profit		$+F$	$-F$					0
Change in money	$-\Delta H_w$	$-\Delta H_\pi$			$+\Delta H_s$			0
Change in loans				$+\Delta L_f$	$-\Delta L_s$		$+\Delta L_{row}$	0
Change in deposits	$-\Delta D_w$	$-\Delta D_\pi$			$+\Delta D_s$			0
Change in shares		$-\Delta e_d \cdot p_e$		$+\Delta e_s \cdot p_e$				0
Change in gov. bonds		$-\Delta B_d$			$-\Delta B_{cb}$	$+\Delta B_s$		0
Σ	0	0	0	0	0	0	0	0
Memo: capital gains		$-\Delta p_e \cdot e_{s,-1}$		$+\Delta p_e \cdot e_{s,-1}$				

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

Budget constraint of firms (identity)

$$L_f = L_{f,-1} + I_c + I_{gr} - AF - \Delta e_s \cdot p_e$$

Selected equations

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Portfolio equation for shares (behavioural)

$$\frac{p_e \cdot e_d}{NW_{\pi,-1}} = \lambda_{10} - \lambda_{11} \cdot r_m - \lambda_{12} \cdot r_b + \lambda_{13} \cdot r_e - \lambda_{14} \cdot \frac{YD_\pi}{NW_{\pi,-1}}$$

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Shares market (equilibrium condition)

$$e_d = p_e \cdot e_s$$

Monetary circuit: initial step

	Households	Production firms		Clearing banks		Σ
		Current	Capital	Current	Capital	
Consumption						-
Investment		$+I$	$-I$			0
Wages	$+WB$	$-WB$				0
Change in loans			$+\Delta L_f$		$-\Delta L$	0
Change in deposits	$-\Delta M_h$		$[-\Delta M_f]$		$+\Delta M$	0
Σ	0	0	0	-	0	0

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- Unlike Solow-like models, SFCMs are not constrained by any supply-side exogenous attractor (e.g. NRU)
- Production and employment are always **demand-led**
- Corollary: **fiscal policies are effective and necessary**, while monetary policies are usually less effective (and counter-intuitive effects, e.g. impact of interest rate changes)

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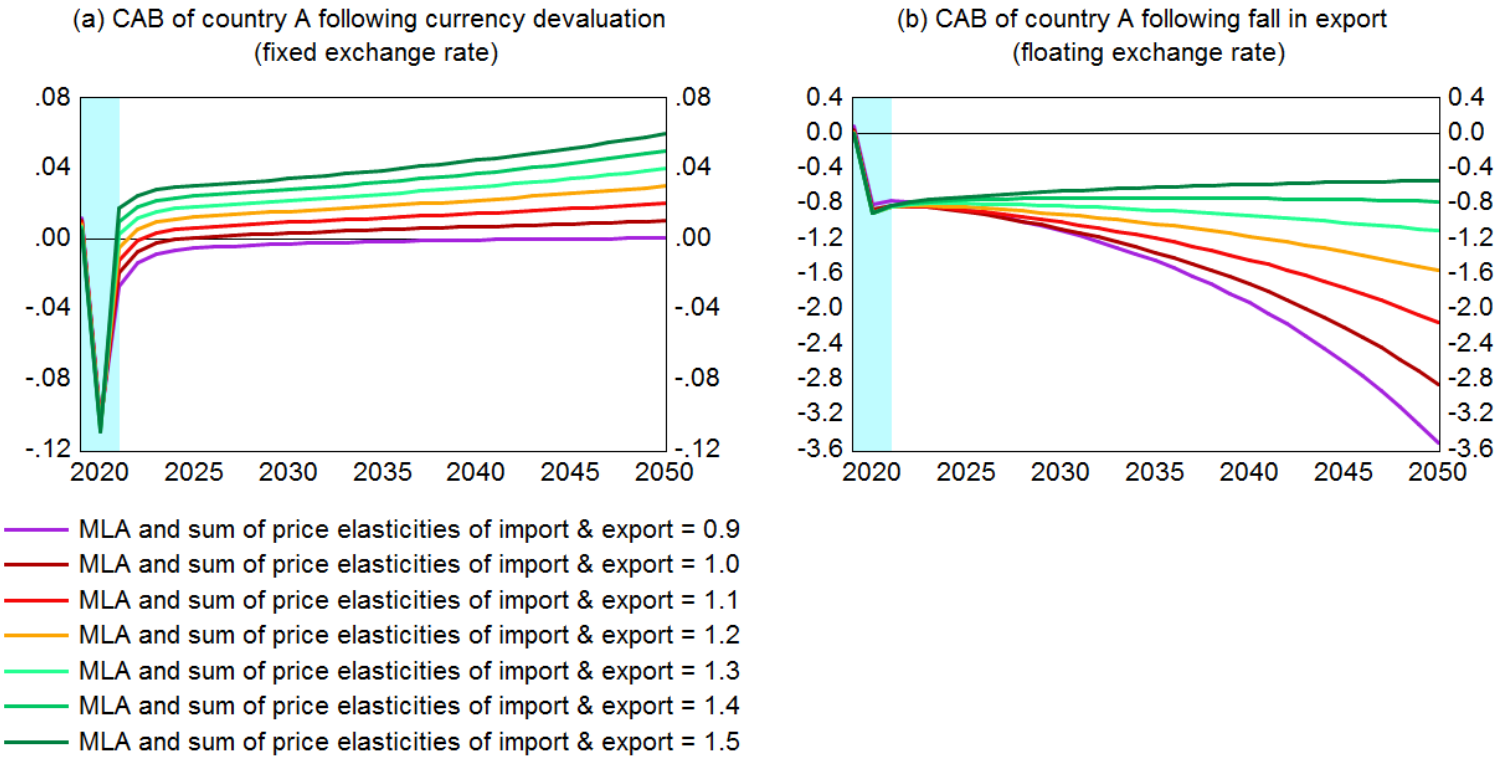
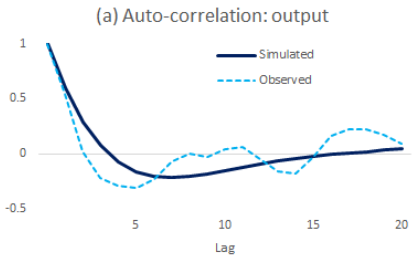
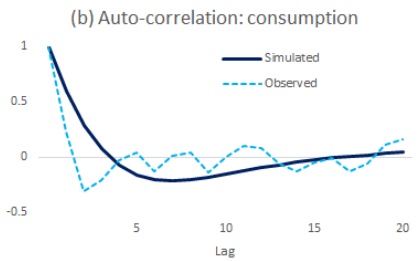
- A variety of **scenarios or shocks** are tested and findings are compared with baseline results (comparative dynamics)
- Findings checked through **sensitivity tests** and **auto- and cross-correlations** analysis

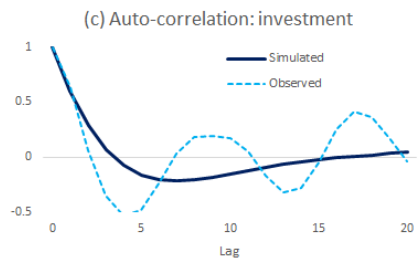
Example of sensitivity test

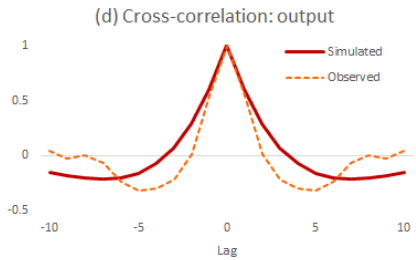


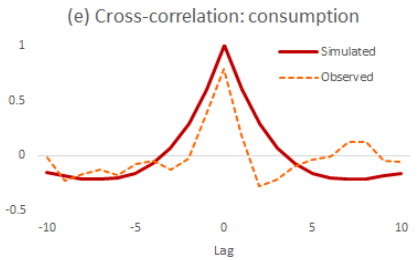
Example of correlation analysis

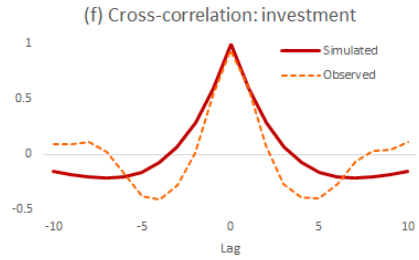












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c) **Types of micro-foundations**. Macro-, meso- or micro-foundation through interacting heterogenous agents, rather than representative agent (or *soft heterogeneity*, e.g. non-Ricardian households) $\Uparrow$

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d) **Intelligibleness of model outcomes**. The interpretation of SFCM outcomes is not always straightforward. By contrast, a DSGE model provides an intuitive narrative and produces a simple VAR representation. Besides, no standard method to match SFC matrices with SNA ⇓

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  - a2) **Input-Output SFCMs**: to analyse dynamic structural change (e.g. Berg et al., 2015)

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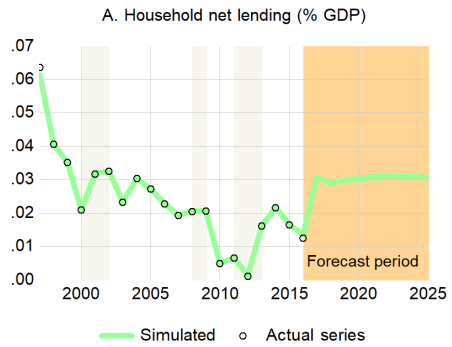
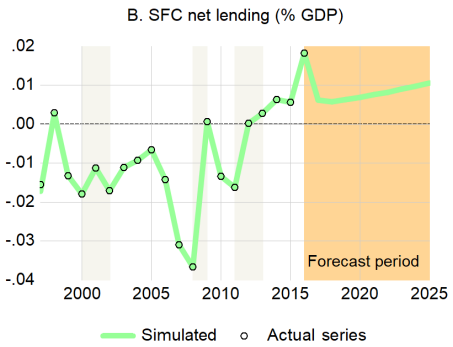
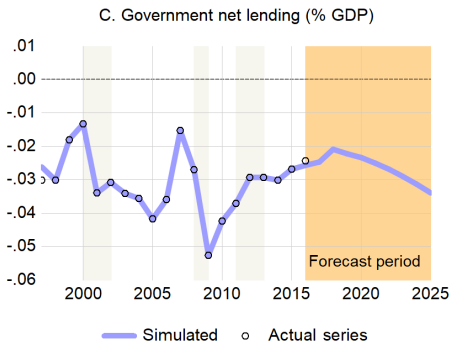
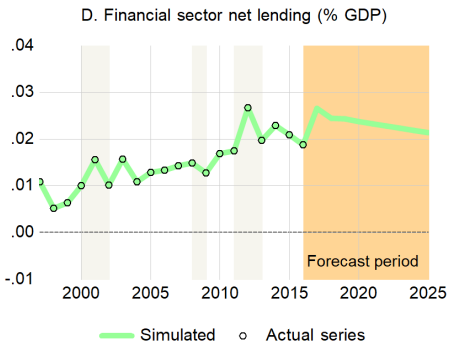
    - b11) *First generation*: Levy-like models, developed starting from available data (e.g. Godley and Zezza 1992) and information not accessible
    - b12) *Second generation*: heavier theoretical structure and information *usually* accessible (e.g. Kinsella and Aliti 2012,2013; Godin et al. 2012; Miess and Schmelzer 2016; BoE 2016; Veronese Passarella 2019)

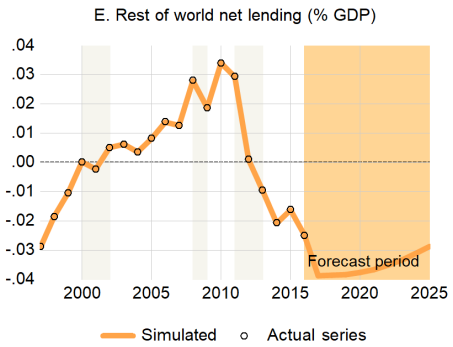
Example of empirical SFC model

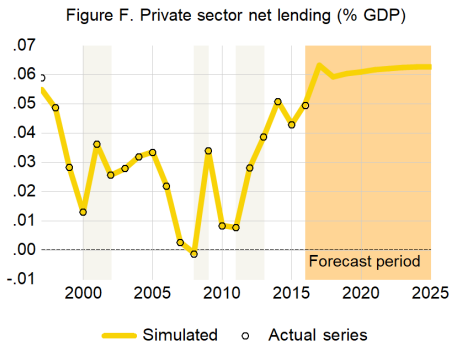












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  - b2) **Open-Economy (or Multi-Country) SFCMs**: one of the most popular applications of SFC method (Lequain 2003; Godley and Lavoie 2007; Lavoie and Zhao 2010; Lavoie and Daigle 2011; Duwicquet et al. 2012; Mazier and Aliti 2012; Mazier and Valdecantos 2015; Zezza and Valdecantos 2015; Ioannou 2018)

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    - addressing the questions of how to finance the transaction towards a 'greener' economy (e.g. Campiglio 2016; Ameli et al. 2017; Rademaekers et al. 2017) and how to tackle climate risks (e.g. Aglietta and Espagne 2016; Bardoscia et al. 2017; Battiston et al. 2017; Bovari et al. 2018; Dafermos et al. 2018)

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b) A **physical stock-flow matrix (PSFM)**, accounting for changes in physical stocks of matter and energy, and in the socio-economic stock

Table 1: physical matrices

(a) Physical flow matrix

	Material balance	Energy balance
Inputs		
Extracted matter	$+mat$	
Renewable energy		$+er$
Non-renewable energy	$+cen$	$+en$
Oxygen	$+O2$	
Outputs		
Industrial CO_2 emissions	$-emis$	
Waste	$-wa$	
Dissipated energy		$-ed$
Change in socio-economic stock	$-\Delta k_{se}$	
Σ	0	0

(b) Physical stock-flow matrix

	Material reserves	Non-Renewable Energy reserves	Atmospheric CO_2 concentration	Socio-economic stock
Initial stock	$k_{m,-1}$	$k_{en,-1}$	$co2_{AT,-1}$	$k_{se,-1}$
Resources converted into reserves	$+conv_m$	$+conv_e$		
Emissions			$+emis$	
Production of material goods				$+y_{mat}$
Extraction/use of matter/energy	$-mat$	$-en$		
Net transfer to oceans/biosphere			$+(\phi_{11}-1)\cdot co2_{AT,-1}$ $+\ \phi_{21}\cdot co2_{UP,-1}$	
Destruction of socio-economic stock				$-des$
Final stock	k_m	k_e	$co2_{AT}$	k_{se}

Note: matter is measured in Gt, while energy is measured in Ej. Hazardous waste not included. See Dafermos et al. (2017, 2018).

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  - k) fixed exchange rate (each CB owns stock of gold reserves to settle international payments)

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  B) Carbonland government reacts **cutting green spending (incentives)**

Table 2: BS of Eco-2C-SFC model

	ECOLAND (*g*)			CARBONLAND (*c*)			
	Households	**Government**	**Central bank**	**Households**	**Government**	**Central bank**	**Σ**
Money	$+H_{gh}$		$-H_{gh}$	$+H_{ch}$		$-H_{ch}$	*0*
Bills	$+B_{gh}$	$-B_g$	$+B_{gcb}$	$-B_{ch}$	$-B_c$	$+B_{ccb}$	*0*
Gold reserves			$+OR_g \cdot p_{org} \cdot E$			$+OR_c \cdot p_{orc}$	$OR_g \cdot p_{org} \cdot E + OR_c \cdot p_{orc}$
Balance (net worth)	$-V_{gh}$	$+V_{gG}$		$+V_{ch}$	$+V_{cG}$		$-(OR_g \cdot p_{org} \cdot E + OR_c \cdot p_{orc})$
Σ	0	0	0	0	0	0	0

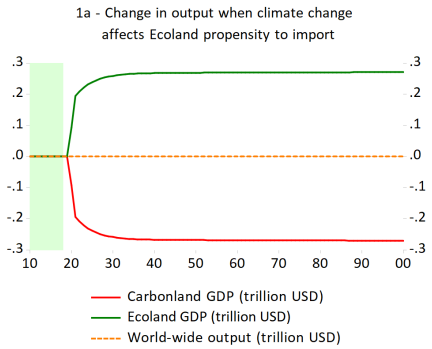
Note: E is the exchange rate. A '+' before a magnitude denotes an asset, whereas '–' denotes a liability

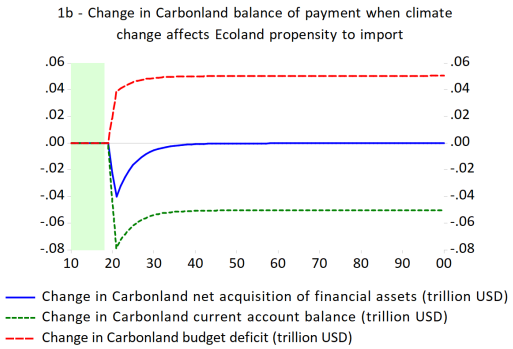
Table 3: TFM of Eco-2C-SFC model

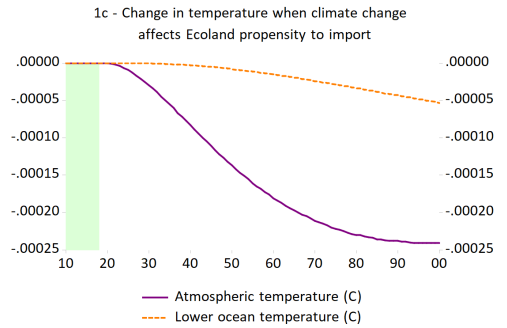
	ECOLAND (*g*)					CARBONLAND (*c*)				
	Households	**Firms**	**Government**	**Central bank**		**Households**	**Firms**	**Government**	**Central bank**	**Σ**
Consumption	$-C_g$	$+C_g$				$-C_c$	$+C_c$			0
Gov. spending		$+G_g$	$-G_g$				$+G_c$	$-G_c$		0
Ecoland export to Carbonland		$+X_g$			$\cdot E$		$-IM_c$			0
Carbonland export to Ecoland		$-IM_g$			$\cdot E$		$+X_c$			0
GDP	$+Y_g$	$-Y_g$				$+Y_c$	$-Y_c$			0
Interests	$+r_{g,-1} \cdot B_{gh,-1}$		$-r_{g,-1} \cdot B_{g,-1}$	$+r_{g,-1} \cdot B_{gcb,-1}$		$+r_{c,-1} \cdot B_{ch,-1}$		$-r_{c,-1} \cdot B_{c,-1}$	$+r_{c,-1} \cdot B_{ccb,-1}$	0
CB profits			$+r_{g,-1} \cdot B_{g,-1}$	$-r_{g,-1} \cdot B_{gcb,-1}$				$+r_{c,-1} \cdot B_{c,-1}$	$-r_{c,-1} \cdot B_{ccb,-1}$	0
Taxes	$-T_g$		$+T_g$			$-T_c$		$+T_c$		0
Change in cash	$-\Delta H_{gh}$			$+\Delta H_{gh}$		$-\Delta H_{ch}$			$+\Delta H_{ch}$	0
Change in bills	$-\Delta B_{gh}$		$+\Delta B_g$	$-\Delta B_{gcb}$		$-\Delta B_{ch}$		$+\Delta B_c$	$-\Delta B_{ccb}$	0
Change in gold				$-\Delta OR_g \cdot p_{org}$	$\cdot E$				$-\Delta OR_c \cdot p_{orc}$	0
Σ	0	0	0	0		0	0	0	0	0

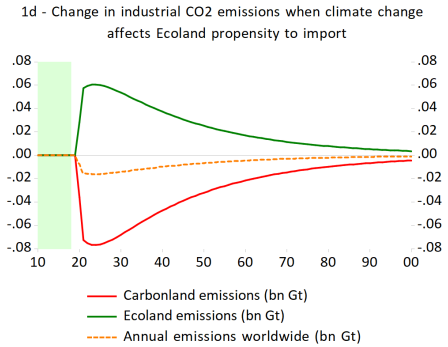
Note: E is the exchange rate. A '+' before a magnitude denotes a receipt or a source of funds, whereas '–' denotes a payment or a use of funds

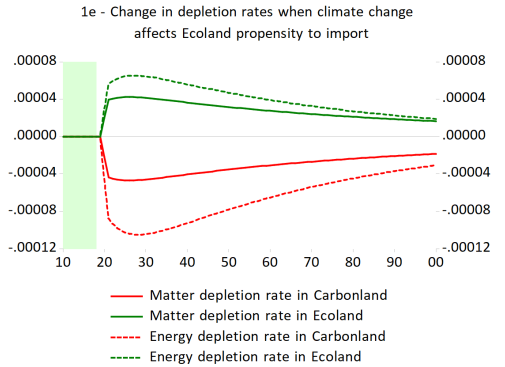
Basic model: preference for *greener* products

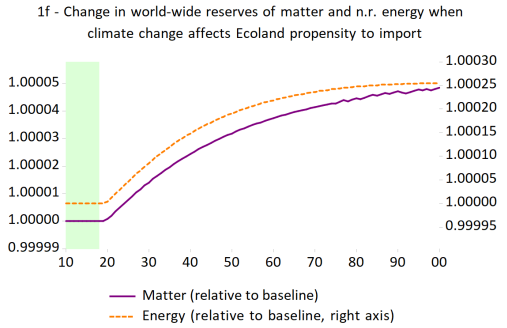




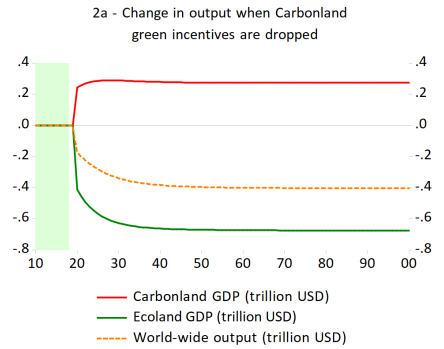


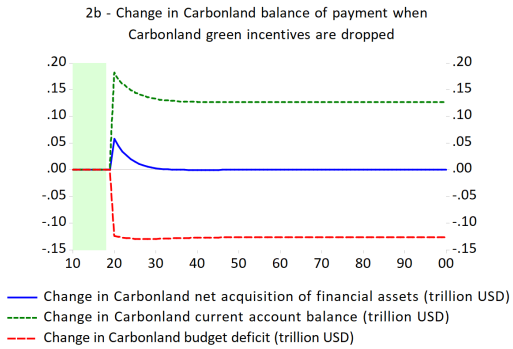


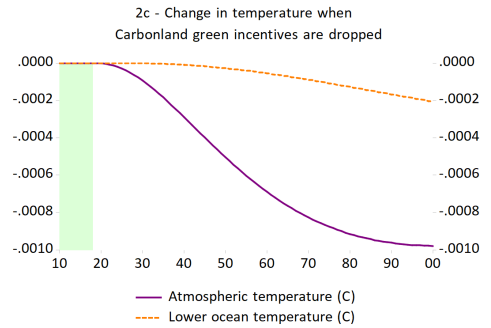


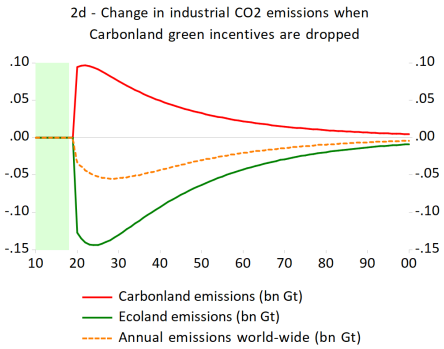


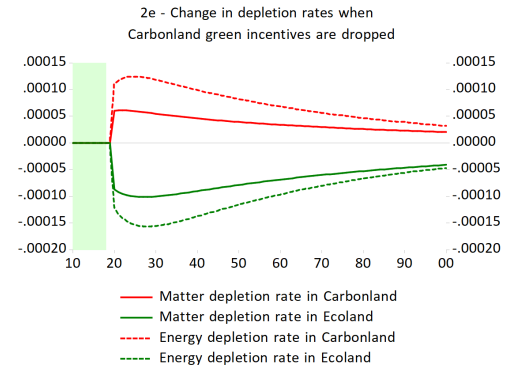
Basic model: cutting green incentives

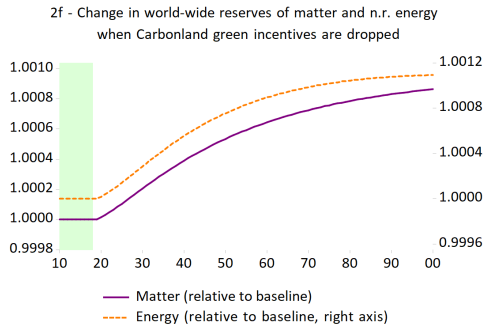




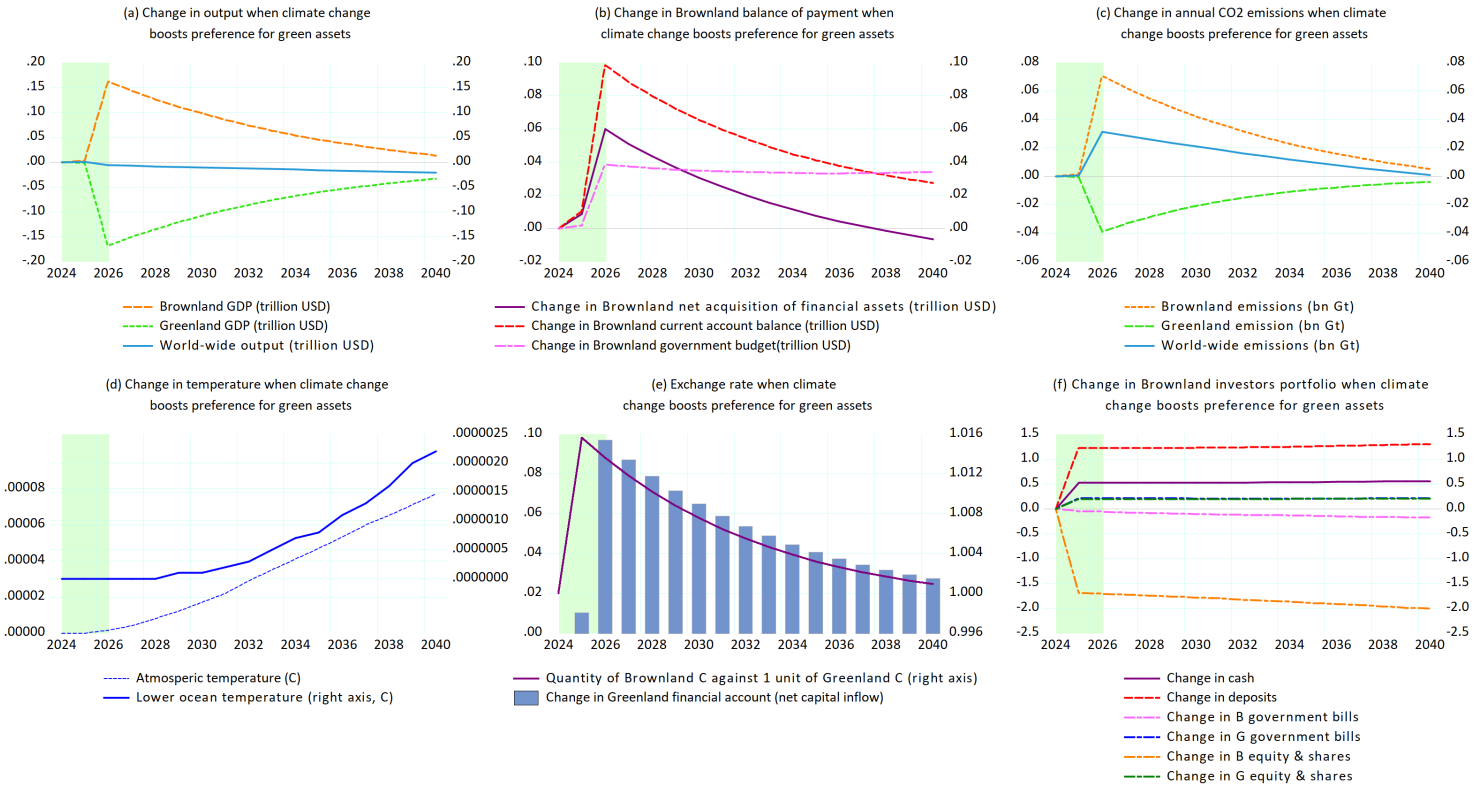








Adv. model: preference for *greener* fin. assets



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- Overall, SFCMs are *effective tools* to analyse *complex* economic systems and their relationship with the ecosystem

Thank You

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