# 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. 1:** to provide a short survey/recap of **SFC literature**
- **Aim no. 2:** to outline a taxonomy of **most recent developments**
- **Aim no. 3:** to develop/present an **ecological two-country model** prototype

# The State of Macro

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

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- **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!**

SFC Dynamic Models

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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

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- Methodological cornerstone: **Copeland (1949)** integrates NIIs with FoFs through the quadruple accounting principle

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- 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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- *The Bible* (*Gospel*): **Godley and Lavoie (2007)**, Monetary Economics: An Integrated Approach to Credit, Money, Income, production and Wealth
- **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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- **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).
- 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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  a) The BS encompasses **assets and liabilities** of each macro-sector (households, firms, banks, central bank, government, foreign sector)
  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



*Table 7.1* Balance sheet of Model *BMW*

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

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

# Example of transactions-flow matrix



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

| | | Production firms | | Banks | | |
|---|---|---|---|---|---|---|
| | **Households** | **Current** | **Capital** | **Current** | **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 |

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

# Selected equations



## Budget constraint of firms (identity)

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

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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)

$$e_d = p_e \cdot e_s$$

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- Corollary: **fiscal policies are effective and necessary**, while monetary policies are usually less effective
- Paradoxes and counter-intuitive effects are possible (e.g. impact of interest rate)

# Main features: calibration

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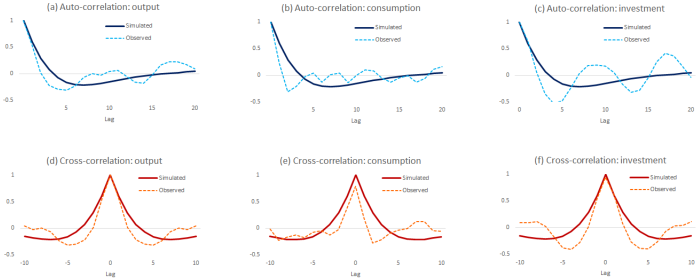
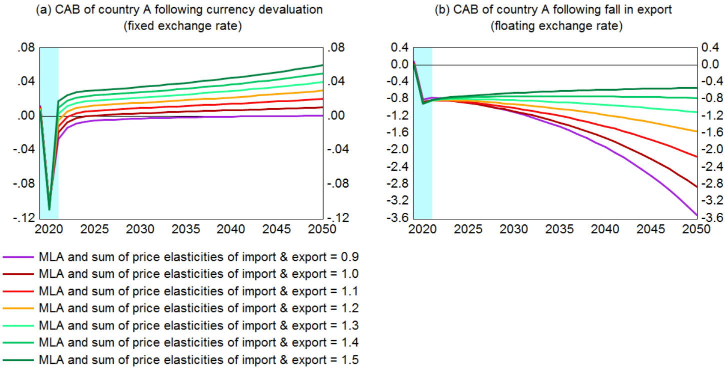
- A variety of **scenarios or shocks** are tested and findings are compared with baseline results (comparative dynamics)
- Robustness checked through **sensitivity tests**

# Example of correlation analysis



# Example of sensitivity test





# SFCMs vs. DSGEMs



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b) **Coefficient estimation methods**. Equation by equation *usually* preferred over system estimation. Inclusion of relevant stocks and flows $\Uparrow$

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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) ⇑

# SFCMs vs. DSGEMs (cont'd)



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Relative strengths and weaknesses of SFCMs:

# SFCMs vs. DSGEMs (cont'd)



Relative strengths and weaknesses of SFCMs:

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 $\Downarrow$

# Recent developments: external



- The first generation of SFCMs has dealt mainly with **financialisation**, **income distribution** and **policy-making**

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  - a1) **Agent-based SFCMs**: to detect the emergent properties of the system resulting from the interaction of a variety of HAs. Financial diseases: bankruptcy chains, financial contagion phenomena, etc. (e.g. Caiani et al., 2016). Effects of distributive inequality and credit constraints (e.g. Cardaci and Saraceno, 2016; Botta et al., 2018)

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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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  - investigating the trajectories of key environmental, macroeconomic and financial variables (e.g. Dafermos et al. 2017, 2018)
  - examining climate change-financial stability nexus (e.g. Dafermos et al. 2018)

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    - analysing the impact of green fiscal policies and green sovereign bonds (Monasterolo and Raberto 2018 and Bovari et al. 2018)
    - 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)

# Recent developments (cont'd)



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# Recent developments (cont'd)



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Eco-SFCM modellers couple standard BS and TFM with:

a) A **physical flow matrix (PFM)**, capturing the I and II Laws of Thermodynamics
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 SF matrix (a) and flow matrix(b)



(*a*)

| | Material reserves | Energy reserves | Atmospheric $CO_2$ concentration | 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.** | $-\Delta K_{se}$ | |
| $\Sigma$ | 0 | 0 |

Note: matter is measured in Gt, while energy is measured in Ej. See Dafermos et al. (2017, 2018) and Carnevali et al. (2019)

# An Eco-2C-SFC prototype

- Eco-SFC models usually focus on a single-area economy, but local impacts of climate change (and natural resources depletion) are likely to be **uneven across countries**

# An Eco-2C-SFC prototype



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  b) balance of payment components and government budgets

# An Eco-2C-SFC prototype

- Three **main blocks** of equations (cont'd):

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# An Eco-2C-SFC prototype

- Three **main blocks** of equations (cont'd):
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    c2) energy resources and reserves, along with $CO_2$ emissions and atmospheric temperature

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  - d) initial government budget and BoP are balanced

# An Eco-2C-SFC prototype (cont'd)

- **Key features** of the model (cont'd):

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# An Eco-2C-SFC prototype (cont'd)



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  g) higher share of renewable energy in Ecoland

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# An Eco-2C-SFC prototype (cont'd)



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- **Auxiliary features** (simplified version only):
  - h) unit prices are fixed (variables expressed at constant prices)
  - i) no fixed capital
  - j) no equity, corporate bonds, deposits and cross-country investments
  - k) fixed exchange rate (each CB owns stock of gold reserves to settle international payments)

- **Key features** of the model (cont'd):



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# An Eco-2C-SFC prototype (cont'd)



- **Key features** of the model (cont'd):

  Realistic baseline: 80 trillion USD under baseline, +1.5C in 2030 (assuming 3% decline in $CO_2$ emissions)

# An Eco-2C-SFC prototype (cont'd)



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  Two shocks:

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  Two shocks:

  A) Higher preference for **green products** ('made in Ecoland')

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  Two shocks:

  A) Higher preference for **green products** ('made in Ecoland')

  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 | $\Sigma$ |
| 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) | $-V_{gh}$ | $+V_{gG}$ | | $+V_{ch}$ | $+V_{cG}$ | | $-(OR_g \cdot p_{org} \cdot E + OR_c \cdot p_{orc})$ |
| $\Sigma$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

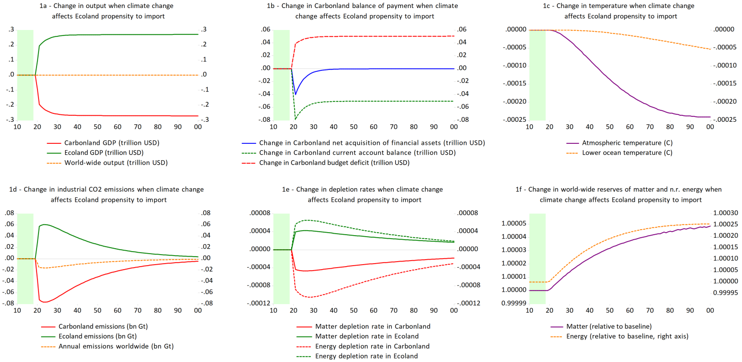
Note: E is the exchange rate. A '+' before a magnitude denotes an asset, whereas '–' denotes a liability

# 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 |

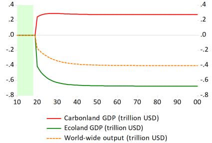
Note: E is the exchange rate. A '+' before a magnitude denotes a receipt or a source of funds, whereas '–' denotes a payment or a use of funds

# Basic model: preference for *greener* products

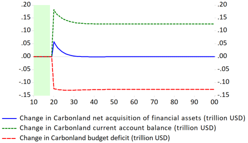


# Basic model: cutting green incentives

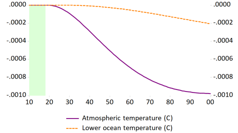
2a - Change in output when Carbonland green incentives are dropped



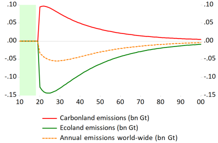

2b - Change in Carbonland balance of payment when Carbonland green incentives are dropped



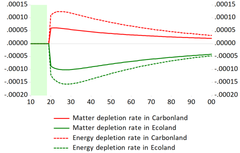

2c - Change in temperature when Carbonland green incentives are dropped



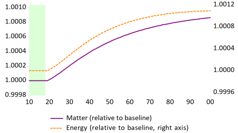

2d - Change in industrial CO2 emissions when Carbonland green incentives are dropped




2e - Change in depletion rates when Carbonland green incentives are dropped




2f - Change in world-wide reserves of matter and n.r. energy when Carbonland green incentives are dropped

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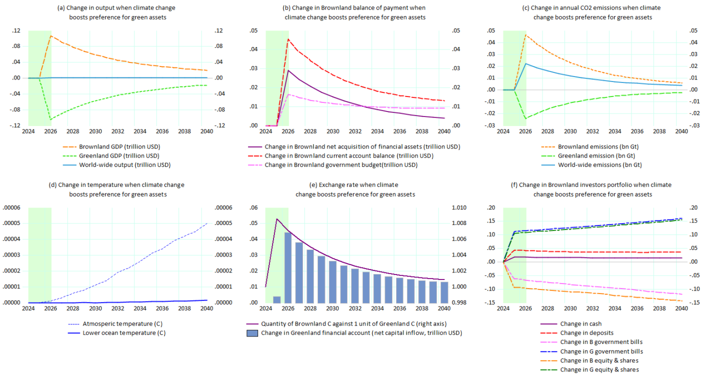
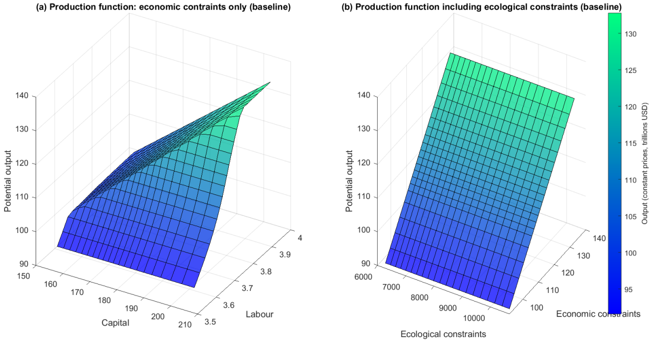
# Adv. model: preference for *greener* fin. assets



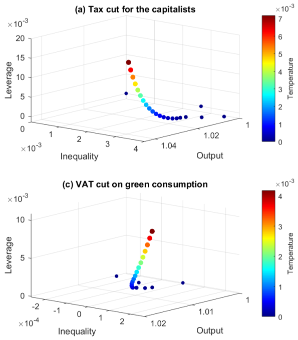
# Leontief production function





# Multiple dimensions





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Main features
SFCMs vs DSGEMs
Recent developments
An Eco-2C-SFC prototype
Advanced features
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- *Powerful tool* to analyse *complex* interactions between economy, finance, ecosystem and society (EFESO)

# Thank You

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