Levy Economics Institute of Bard College

Stock-Flow Consistent Modeling in Ecological Economics

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SFC & Ecological Economics

1 SFC-Ecological Economics

- Many environmental processes can be formalized through the stock-flow relationship. For instance, the flow of CO2 emissions accumulate in a stock of CO2 pollution
- There are interdependencies of these processes with the real and the financial sector of an economy. E.g.,the flow of emissions will depend on industrial processes in a given region/economy, and and the stock of emissions has adverse consequences on quality of life and the economy.
- Hence the SFC approach can be used to study issues related to ecological economics.

Exist several good examples of this literature

1. **Climate and energy transition risks in traditional SFC models**: Monasterolo and Raberto (2018) , Dunz et al. (2020) , Godin (2013) , Yajima (2023).
2. **Emissions modeling in an SFC macro setting**: Naqvi and Stockhammer (2017), Valdecantos (2021), Passarella et al. (2022), Zezza, F. et al. (forthcoming)
3. **Stock-Flow-Fund models** : Dafermos et al. (2017), Berg et al. (2015), Carnevali et al. (2021)

Simulation results

1 SFC-Ecological Economics

Assessing the economic consequences of an energy transition through a biophysical stock-flow consistent model

		Biophysical constraints									Model of the economy				
		Energy			Materials			Waste			Eq. mechanism	Sectors included			
Model	Authors	Av. NRE	Av. RE	EROI	Av.	EI	Biodiv.	Poll.	GHG	CD	Demand-driven	Gov.	CB	RoW	Multi-sect.
n/a	Barth and Richters (2019)	×	×	✓	×	×	×	×	✓	×	✓	✓	×	×	×
n/a	Berg et al. (2015)	×	×	✓	×	×	×	×	✓	✓	×	✓	×	×	×
GEMMES	Bovari et al. (2018a)	×	×	×	×	×	×	×	✓	✓	×	×	×	×	×
GEMMES	Bovari et al. (2018b)	×	×	×	×	×	×	×	✓	✓	×	×	×	×	×
GEMMES	Bovari et al. (2020)	×	×	×	×	×	×	×	✓	✓	×	×	✓	×	×
n/a	Carnevali et al. (2021)	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	✓	✓	✓
n/a	Dafermos et al. (2017)	✓	×	×	✓	×	×	✓	✓	✓	✓	×	×	×	×
DEFINE	Dafermos et al. (2018)	✓	×	×	✓	×	×	✓	✓	✓	✓	✓	✓	×	×
Eurogreen	D'Alessandro et al. (2020)	×	×	×	×	×	×	×	✓	×	✓	✓	×	✓	✓
n/a	Deleidi et al. (2019)	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	✓	✓	✓
n/a	Gonzalez-Redin et al. (2018)	×	✓	×	×	×	×	×	×	×	×	✓	×	×	×
LowGrow	Jackson and Victor (2020)	×	×	✓	×	×	×	×	✓	×	✓	✓	✓	✓	✓
TranSim	Jackson and Jackson (2021)	×	×	✓	×	×	×	×	×	×	✓	×	×	×	×
HARMONEY	King (2020, 2021)	✓	×	✓	×	×	×	×	×	×	✓	×	×	×	×
n/a	Naqvi (2015)	✓	×	✓	×	×	×	×	✓	×	✓	✓	×	✓	✓
n/a	Naqvi and Stockhammer (2018)	×	×	×	×	×	×	×	✓	×	✓	✓	×	×	×
SFCIO-IAM	Sers (2021)	×	×	✓	×	×	×	×	✓	✓	✓	✓	×	×	✓
TEMPLE	This paper	×	✓	✓	×	×	×	×	×	×	✓	✓	✓	×	✓

Table 1
Identified biophysical SFC models. A check in a column means that the model is taking into consideration the biophysical constraint to growth or is including the sector in its stock-flow consistent description of the economy. "Av. NRE"=Availability of Non-Renewable Energy. "Av. RE"=Availability of Renewable Energy. "Av."=Availability [of materials]. "EI"=Energy Intensity. "Biodiv."=Biodiversity loss. "Poll."=Pollutants directly affecting human health (e.g. fine particles). GHG=Greenhouse Gases emissions. "CD"=Climate Damage through feedback loop. "Gov."=Government. "CB" =Central Bank. "RoW"=Rest of the World (multi-regional model). "Multi-sect"=Multi-sectorial model.

Based on Jacques, P., Delannoy, L., Andrieu, B., Yilmaz, D., Jeanmart, H., & Godin, A. (2022).

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2 ELR and GND

Motivation

2 ELR and GND

We argue that a careful design of a scheme of direct employment and public provision by the state can have permanent effects and promote the structural and environmental transformation of the economy, thus overcoming the usual criticism attached to this proposal;

To illustrate this point, we develop a Stock-Flow Consistent (SFC) model based on Godin (2014) and Sawyer and Passarella (2021) in order to study the long run effect of the implementation of a Job Guarantee program.

The ELR...

2 ELR and GND

- The current health and economic crisis has revived the interest on policies that target employment directly instead of trying to achieve it via a general "demand push". One of these proposals is the *Job Guarantee (JG) or Employer of last resort policy (ELR).*
- This proposal was developed by Minsky (1965, 1968, 1994), which saw it as a necessary counterpart of the Fed role as "Lender of last Resort" (LLR) in financial markets in order to *"Stabilize an Unstable Economy"*, subject to cyclical fluctuations due to the decisions and expectations of the private sector, seldom driven by rational decisions (Minsky 2008).

The (GND) ELR...

2 ELR and GND

It has been increasingly intertwining with the Green New Deal (GND), a policy proposal to increase energy efficiency and promote both environmental and social sustainability;

- **A Green ELR** targeting labour force with below-average skills and labour-intensive vacancies (care services, small construction and retrofitting interventions);
- **A boost to aggregate demand**: For a net annual impact on the federal government's budget of roughly 400 USD billion per year over 10 years, there will be a boost to GDP of 560 USD billion annually and to employment of 19 million new workers;
- **Both the quantity and the quality of the workforce is affected**: the increased labor demand in the economy forces disguised unemployment to shrink, whilst workers employed in the scheme improve their productivity.

...and its Critics

2 ELR and GND

Over the years, the ELR proposal has received a number of criticism, in particular on:

1. The impact on both the government budget and debt (Aspromourgos 2000; Sawyer 2003);
2. The prevailing full-employment equilibrium wage rate once the program is implemented (Seccareccia 2004);
3. The implication on the external balances (current and trade account), especially when this policy is implemented in a small, open economy (Epstein 2019; Vernengo and Perez Caldentey 2020).

...and its Critics

2 ELR and GND

There are a few observations that can be identified in the GND version of the ELR:

1. It is hard to imagine an enhancement of productivity of the labour force similar to education;
2. The negative consequences from the reduction of a component of aggregate demand would still affect the economy;
3. Absence of “rebounding” effects (increase in energy consumption following the improvement in energy efficiency)

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3 The Model

The Model

3 The Model

Our economy is composed by 8 sectors:

- a productive sector, composed by the consumption goods firms, investment firms and energy firms;
- a banking sector;
- a government;
- a central bank;
- a foreign sector;
- an households sector, composed by rentiers and workers.

The main innovations with respect to the benchmark models are:

1. a more complex financial structure;
2. an explicit distinction between the government and the CB;
3. a simplified foreign sector.

Accounting Framework

3 The Model

name	Households	Firms e	Firms c	Firms k	Financial Sector	Government	Central bank	Foreign Sector	sum
cheque deposits	$+m1h$				$-m1h$				0
Saving deposits	$+m2h$				$-m2h$				0
Bills	$+bh$				$+bb$	$-bs$	$+bcb$		0
Loans	$-lh$	$-lf_e$	$-lf_c$	$-lf_k$	$+ls$				0
Securities	$+eh$	$-eh_e$	$-eh_c$	$-eh_k$					0
Capital		$+k_e$	$+k_c$	$+k_k$					K
Cash	$+hh$						$-hh$		0
Advances					$-ad$		$+ad$		0
Reserves					$+hbd$		$-hbd$		0
Foreign Reserves					$+hf$			$-hf$	0
Balance	$-V$	NWe	NWc	NWk	NWb	NWg	$NWcb$	NWf	0

Accounting Framework

3 The Model

name	Households	Firms e	Firms c	Firms k	Financial Sector	Government	Central bank	Foreign Sector	sum
Consumption	$-c$		$+y_c$			$-c_{g,c}$			0
Energy Consumption	$-c_e$	$+y_e$	$-c_c$	$-c_k$		$+c_{g,e}$			0
Govt. Expenditures		$+c_{g,e}$	$+c_{g,c}$	$+c_{g,k}$		$-gov$			0
Investment		$-id_e$	$-id_c$	$+y_k$		$-c_{g,k}$			0
Firms' Profit	$+fdf$	$-fdf_e$	$-fdf_c$	$-fdf_k$					0
Taxes	$-tax$					$+tax$			0
Banks Profits	$+fb$				$-fb$				0
CB Profits						$+fcb$	$-fcb$		0
Exports			$+x$					$-x$	0
Imports			$-m$					$+m$	0
Int. on cheque deposits	$+rm_{-1} * m1h_{-1}$				$-rm_{-1} * m1h_{-1}$				0
Int. on Saving deposits	$+rm_{-1} * m2h_{-1}$				$-rm_{-1} * m2h_{-1}$				0
Int. on Bills	$+rb_{-1} * bh_{-1}$				$+rb_{-1} * bb_{-1}$	$-rb_{-1} * bs_{-1}$	$+rb_{-1} * bcb_{-1}$		0
Int. on Loans	$-rl_{h,-1} * lh-1$	$-rl_{e,-1} * lf_{e,-1}$	$-rl_{c,-1} * lf_{c,-1}$	$-rl_{k,-1} * lf_{k,-1}$	$+rl_{x,-1} * ls_{x,-1}$				0
Int. on Securities	$+re_{x,-1} * eh_{x,-1}$	$-re_{e,-1} * eh_{e,-1}$	$-re_{c,-1} * eh_{c,-1}$	$-re_{k,-1} * eh_{k,-1}$					0
Int. on Advances					$-ra_{-1} * ad_{-1}$		$+ra_{-1} * ad_{-1}$		0
Int. on Reserves					$+rh_{-1} * hbd_{-1}$		$-rh_{-1} * hbd_{-1}$		0
Change in cheque deposits	$-\Delta m1h$				$+\Delta m1h$				0
Change in Saving deposits	$-\Delta m2h$				$+\Delta m2h$				0
Change in Bills	$-\Delta bh$				$-\Delta bb$	$+\Delta bs$	$-\Delta bcb$		0
Change in Loans	$+\Delta lh$	$+\Delta lf_e$	$+\Delta lf_c$	$+\Delta lf_k$	$-\Delta ls$				0
Change in Securities	$-\Delta eh$	$+\Delta eh_e$	$+\Delta eh_c$	$+\Delta eh_k$					0
Change in Cash	$-\Delta hh$						$+\Delta hh$		0
Change in Advances					$+\Delta ad$		$-\Delta ad$		0
Change in Reserves					$-\Delta hbd$		$+\Delta hbd$		0
Change in Foreign Reserves					$-\Delta hf$			$+\Delta hf$	0

Non-financial firms

3 The Model

Total Output[1] (1) is the sum of outputs in three productive sectors: consumption/widgets (y_c), investment (y_k), and energy (y_e).

$$y = y_c + y_k + y_e \tag{1}$$

The demand in sector c (2) includes households' consumption, government expenditures, and net exports. It is assumed that only this sector is involved in international trade.

$$y_c = c + c_{g,c} + tb \tag{2}$$

The investment sector k receives investment demand from all sectors and government demand (3).

$$y_k = \sum_{x=1}^{n} id_x + c_{g,k}, \forall x \in \{c, k, e\} \tag{3}$$

[1] The reader may find in the appendix the complete presentation of all the symbols

Non-financial firms

3 The Model

The energy sector e accommodates demand from c, k, households, and government (4).

$$y_e = \ c_c + \ c_k + \ c_{g,e} + \ c_e \tag{4}$$

Sectors c and k use energy based on productivity (5).

$$c_x = \frac{y_x}{pre}, \forall x \in \{c, k\} \tag{5}$$

Household energy consumption is a fraction of lagged consumption (6).

$$c_e = \sigma_3 * (\ c_{-1}) \tag{6}$$

Non-financial firms

3 The Model

Firms aim to reach a target capital stock based on past demand (7), and depreciation is a fixed proportion of existing capital stock (8). Amortization funds match depreciation (9).

$$kt_x = \kappa_x * \ y_x * \frac{ep}{p}, \forall x \in \{c, k, e\} \tag{7}$$

$$da_x = \delta * \ k_{x,-1}, \forall x \in \{c, k, e\} \tag{8}$$

$$af_x = \ da_x, \forall x \in \{c, k, e\} \tag{9}$$

Non-financial firms

3 The Model

Investment demand (10) covers both depreciation and the capital gap to the target.

$$id_x = \gamma_x * (\ kt_x - \ k_{x,-1}) + \ da_x, \forall x \in \{c, k, e\} \tag{10}$$

Capital stock grows accordingly (11).

$$k_x = \ k_{x,-1} + \ id_x - \ da_x, \forall x \in \{c, k, e\} \tag{11}$$

Profits are residuals after paying wages, depreciation, interest on debt, and energy costs (13).

$$ff_x = \ y_x - \ rl_{x,-1} * \ lf_{x,-1} - \ af_x - \ wb_x - \ c_x, \forall x \in \{c, k\} \tag{12}$$

$$ff_e = \ y_e - \ rl_e{-}1 * \ lf_e{-}1 - \ af_e - \ wb_e \tag{13}$$

Non-financial firms

3 The Model

Profits are split into retained earnings (internal funds, 14) and distributed funds (15).

$$fdf_x = (1 - theta_x) * ff_x, \forall x \in \{c, k, e\} \tag{14}$$

$$fuf_x = theta_x * ff_x, \forall x \in \{c, k, e\} \tag{15}$$

Loan demand covers the gap between investment and internal funds, net of equity issuance (16).

$$lf_x = lf_{x,-1} + id_x - af_x - fuf_x - (esr_x - esr_{x,-1}) * pe_x, \forall x \in \{c, k, e\} \tag{16}$$

Equity issuance is modeled proportionally to past investment (104).

$$esr_x = esr_{x,-1} + chi * \frac{id_{x,-1}}{pe_{x,-1}}, \forall x \in \{c, k, e\} \tag{17}$$

Households

3 The Model

Households' disposable income (93) consists of:

- Wages from both private and public Job Guarantee (JG) sectors,
- Distributed profits from firms and banks,
- Interest received on deposits and government bonds,
- Government transfers.

From this, we subtract taxes and public tariffs.

$$yd = wb + rm_{-1} * m2h_{-1} + rb_{-1} * bh_{-1} + fdf + fb + tr - tax + wbg - cgov \tag{18}$$

Aggregate consumption (103) depends on:

- Real disposable income (adjusted by price ratio),
- Wealth (various financial assets),
- Minus household energy consumption.

Households

3 The Model

$$c = \alpha_1 * \ yd * \frac{ep}{p} + \alpha_2 * \ hh_{-1} + \alpha_3 * \ m1h_{-1} + \alpha_4 * \ m2h_{-1} \ + \alpha_5 * \ bh_{-1} + \alpha_6 * \ eh_{-1} \ - c_e \tag{19}$$

Private wage income is the sum of wages across all production sectors (20).

$$wb = \sum_{x=1}^{n} \ wb_x, \forall x \in \{c, k, e\} \tag{20}$$

The propensity to consume from income (α_1) is endogenized based on policy rate and unemployment (21).

$$\alpha_1 = \alpha_{10} - \alpha_{11} * \ {r_{-1}}^{\star} - \alpha_{12} * un_{-1} \tag{21}$$

Households

3 The Model

Household wealth (22) is defined in the Haig-Simmons tradition, combining:

- Previous net wealth,
- Current disposable income,
- Capital gains on equities (23),
- Minus consumption.

$$vh = \ nvh_{-1} + \ yd + \ cg - \ c \tag{22}$$

Households

3 The Model

Capital gains (cg) are derived from changes in equity prices and households' share holdings:

$$cg = \sum_{x=1}^{n} esr_{x,-1} * \ (pe_x - pe_{x,-1}), \forall x \in \{c, k, e\} \tag{23}$$

The aggregate wage share (Ω) includes both private and public employment:

$$\Omega = \frac{(wb + wbg)}{y} \tag{24}$$

Commercial banks

3 The Model

Banks accommodate firms' credit demand (26), which originates from the sum of loans required in each sector (25).

$$lf = lf_c + lf_e + lf_k \tag{25}$$

$$ls = lf \tag{26}$$

They also collect deposits from households in the form of:

- Checking accounts (27),
- Saving deposits (28).

$$m1s = m1h \tag{27}$$

$$m2s = m2h \tag{28}$$

Commercial banks

Banks' profits (29) are fully distributed to households. These profits are generated from:

- Interest on loans to firms,
- Interest on government bills,
- Minus interest paid on deposits and advances,
- Plus returns on reserves held at the central bank.

$$fb = \sum_{x=1}^{n} rl_{x,-1} * lf_{x,-1} + rb_{-1} * bb_{-1} - rm_{-1} * m2s_{-1} \\ - ra_{-1} * ad_{-1} + rh_{-1} * (hbd_{-1} + hbd_{-1}^{\star}), \forall x \in \{c, k, e\} \tag{29}$$

Commercial banks

3 The Model

The notional demand for government bills (30) is calculated as the excess of deposits over credit and reserve holdings.

$$bb_{not} = \ m1s + \ m2s - \ ls - \ hbd \tag{30}$$

This notional demand determines the allocation between:

- Treasury bills (31),
- Extra reserves at the central bank (32),
- Or, if negative, the need for advances from the central bank (33).

$$if(bb_{not} > 0)\ bb = bb_{not} * \beta\ else\ bb = 0 \tag{31}$$

$$if(bb_{not} > 0)\ hbd^{\star} = \ bb_{not} * \ (1 - \beta)\ else\ hbd^{\star} = 0 \tag{32}$$

$$if(bb_{not} > 0)\ ad = 0\ else\ ad = \ -bb_{not} \tag{33}$$

Government

3 The Model

The government levies taxes on labor income, capital income, and wealth (34). Transfers to households include:

- An autonomous component, and
- A counter-cyclical component that increases with unemployment (35).

$$tax = \tau_0 + \tau_1 * wb + \tau_2 * (rm_{-1} * m2h_{-1} + rb_{-1} * bh_{-1} + fdf + fb) + \tau_3 * vh_{-1} \quad (34)$$

$$tr = \tau_4 + \tau_5 * un_{-1} \quad (35)$$

Government

Government consumption is fully induced and pro-cyclical, depending on the previous period's sectoral outputs (37-39):

$$gov = \ c_{g,c} + \ c_{g,k} + \ c_{g,e} \tag{36}$$

$$c_{g,k} = \sigma_1 * (y_{k,-1}) \tag{37}$$

$$c_{g,c} = \sigma_0 * (y_{c,-1}) \tag{38}$$

$$c_{g,e} = \sigma_2 * \ (y_{e,-1}) \tag{39}$$

Government

3 The Model

The government deficit (40) includes:

- Government spending on goods and services (`gov`),
- Transfers to households (`tr`),
- Interest payments on public debt,
- Minus taxes and central bank profits.

It is financed through the issuance of new government bills (41).

$$def = gov + tr + rb_{-1} * bs_{-1} - tax - fcb + wbg - cgov \tag{40}$$

$$bs = bs_{-1} + def \tag{41}$$

Portfolio Decisions

3 The Model

Households allocate their wealth across financial assets according to Tobinesque principles. Their portfolios include:

- Shares (equity),
- Government bills,
- Checking and saving deposits.

Shares are supplied on demand by firms and expressed in real terms:

Portfolio Decisions

3 The Model

$$esr = \sum_{x=1}^{n} esr_x, \forall x \in \{c, k, e\} \tag{42}$$

$$ehr = \sum_{x=1}^{n} ehr_x, \forall x \in \{c, k, e\} \tag{43}$$

$$ehr_x = esr_x, \forall x \in \{c, k, e\} \tag{44}$$

$$eh = \sum_{x=1}^{n} eh_x, \forall x \in \{c, k, e\} \tag{45}$$

$$eh_x = ehr_x * pe_x, \forall x \in \{c, k, e\} \tag{46}$$

Portfolio Decisions

3 The Model

Asset demand follows a Tobinesque allocation rule, incorporating:

- Wealth effects,
- Relative returns (interest and equity yields),
- Disposable income (transaction motive).

$$\begin{bmatrix} bh \\ m1h \\ pe_c \cdot ehr_c \\ pe_k \cdot ehr_k \\ pe_e \cdot ehr_e \end{bmatrix} = \begin{bmatrix} \lambda_{10} \\ \lambda_{20} \\ \lambda_{30} \\ \lambda_{40} \\ \lambda_{50} \end{bmatrix} \cdot vh_{-1} + \begin{bmatrix} \lambda_{11} & \lambda_{12} & \lambda_{14} & \lambda_{15} & \lambda_{16} \\ \lambda_{21} & \lambda_{22} & \lambda_{24} & \lambda_{25} & \lambda_{26} \\ \lambda_{31} & \lambda_{32} & \lambda_{34} & \lambda_{35} & \lambda_{36} \\ \lambda_{41} & \lambda_{42} & \lambda_{44} & \lambda_{45} & \lambda_{46} \\ \lambda_{51} & \lambda_{52} & \lambda_{54} & \lambda_{55} & \lambda_{56} \end{bmatrix} \cdot \begin{bmatrix} rb_{-1} \\ rm_{-1} \\ re_{c,-1} \\ re_{k,-1} \\ re_{e,-1} \end{bmatrix} \cdot vh_{-1} + \begin{bmatrix} \lambda_{13} \\ \lambda_{23} \\ \lambda_{33} \\ \lambda_{43} \\ \lambda_{53} \end{bmatrix} \cdot yd_{-1} \tag{47}$$

Portfolio Decisions

3 The Model

Households also hold cash for transactions, and saving deposits adjust residually:

$$hh = \lambda_c \cdot c \cdot \frac{ep}{p} \tag{48}$$

$$m2h = vh - hh - m1h - bh - eh \tag{49}$$

Central bank

3 The Model

The Central Bank commits to purchase all the bills left unsubscribed, in accordance with its function as LLR (50). Cash matches the bills purchased by the monetary authority plus advances minus reserves (both standard and extra, 51-55-56). Advances (52) are supplied on demand by the Central Bank, whilst reserves depend on the legal requirements imposed to banks' deposits (54). Central Bank profits are entirely transferred to government (53).

$$bcb = bs - bh - bb \tag{50}$$

$$hs = bcb + as - (hbs + hbs^{\star}) + hf \tag{51}$$

$$as = ad \tag{52}$$

Central bank

3 The Model

$$fcb = \ rb_{-1} * \ bcb_{-1} + \ ra_{-1} * \ as_{-1} - \ rh_{-1} * \ (hbs_{-1} + hbs_{-1}^{\star}) \tag{53}$$

$$hbd = \rho 1 * \ m1s_{-1} + \rho 2 * \ m2s_{-1} \tag{54}$$

$$hbs = \ hbd \tag{55}$$

$$hbs^{\star} = \ hbd^{\star} \tag{56}$$

Quantitative easing

3 The Model

When the monetary authority conducts OTM with the private sector, it targets a certain share of the existing stock of bills issued (57). This share is a function of an exogenous target minus the policy rate (58). As rates approach the zero lower bound, the QE share increases.

$$bcb = \ bs_{-1} * \ vareps \tag{57}$$

$$vareps = \ vareps_0 - \ vareps_1 * \ r^{\star} \tag{58}$$

Quantitative easing

3 The Model

As QE is implemented, Central Bank purchases bills directly from households. This affects cash holdings (59-60) and bill demand (61). These equations replace the standard cash and bill equations (50-51).

$$hh = \ hh + \ bh - \ (bs - bb - bcb) \tag{59}$$

$$hs = \ hh \tag{60}$$

$$bh = \ bs - \ bb - \ bcb \tag{61}$$

Interest rates

3 The Model

The yields in the financial sector are mostly set by the policy rate defined by the Central Bank, plus exogenous mark-ups (63-67). Only the yield on corporate securities is determined endogenously via dividends and equity holdings (62).

$$re_x = \frac{fdf_x}{eh_{x,-1}} \ , \forall x \in \{c, k, e\} \tag{62}$$

$$rb = r^\star + mub \tag{63}$$

$$rl_x = r^\star + mul_x, \forall x \in \{c, k, e\} \tag{64}$$

$$rm = r^\star + mum \tag{65}$$

$$ra = r^\star + mua \tag{66}$$

Interest rates

3 The Model

The only endogenous mark-up is on bills. It adjusts inversely to changes in the share of bills purchased by the private sector (68-69).

$$mub = mub_0 - mub_1 * (bpr - bpr_{-1}) \tag{68}$$

$$bpr = \frac{(bh + bb)}{bs} \tag{69}$$

Labour market

3 The Model

Labour demand for each sector is simply defined as the ratio between the demand and the labour productivity minus tariffs (71). The workforce grows at an exogenous growth rate but it endogenously adjusts to labour demand in the private sector (72). Nominal wages (74-75-76) in each sector depend upon both real wages and the adjustment of the actual to the non-inflationary rate of unemployment, which is set to zero.

$$wb_x = w * nd_x, \forall x \in \{c, k, e\} \tag{70}$$

$$nd_x = \frac{(y_x - cgov)}{prf_x}, \forall x \in \{c, k, e\} \tag{71}$$

$$ns = ns_{-1} * (1 + gl) + nu * (nd_{-1} - ns_{-1}) \tag{72}$$

$$wb = wb_{-1} * \left(\frac{nd}{ns_{-1}}\right) \tag{73}$$

Labour market

3 The Model

$$w_e = (1 - \omega_1 * (un_{-1} - nun)) * ep * \frac{w_{e,-1}}{p_{-1}} \tag{74}$$

$$w_c = (1 - \omega_2 * (un_{-1} - nun)) * ep * \frac{w_{c,-1}}{p_{-1}} \tag{75}$$

$$w_k = (1 - \omega_3 * (un_{-1} - nun)) * ep * \frac{w_{k,-1}}{p_{-1}} \tag{76}$$

$$w = \frac{(w_c + w_e + w_k)}{3} \tag{77}$$

$$prf = \frac{(prf_c + prf_e + prf_k)}{3} \tag{78}$$

Prices and expectations

3 The Model

Prices in the private sector are determined as a simple mark up over unit labour costs (79). The general level of prices (81) includes the costs of public goods and their production costs, given by the labour force in the JG sector (80, more on this in Section 4). Inflation expectations are assumed to be adaptive (83-83).

$$pf = (\frac{w}{prf}) * \ (1 + \ mup) \tag{79}$$

$$pg = \frac{cgov}{(prg * \ ng)} \tag{80}$$

$$p = \ pf * \ (1 - \ (\frac{cgov_{-1}}{y_{-1}})) + \ pg * \ (\frac{cgov_{-1}}{y_{-1}}) \tag{81}$$

Prices and expectations

3 The Model

$$\pi = (\frac{p}{p_{-1}}) - 1 \tag{82}$$

$$epi = epi_{-1} + \psi_1 + \psi_2 * (\pi_{-1} - epi_{-1}) \tag{83}$$

$$ep = \ p_{-1} * \ (1 + \ epi) \tag{84}$$

Foreign sector and Redundant equation

3 The Model

Exports and imports appear only in the widget sector and are modeled in logarithmic form. They depend on the nominal exchange rate, foreign output (sector c), and local prices:

$$ex = \xi_0 + \xi_1 \cdot \log(xr_{-1}) + \xi_2 \cdot \log(y_{f,-1}) + \xi_3 \cdot \log(p_{-1}) \tag{85}$$

$$im = \mu_0 + \mu_1 \cdot \log(xr_{-1}) + \mu_2 \cdot \log(y_{c,-1}) + \mu_3 \cdot \log(p_{-1}) \tag{86}$$

Foreign output grows at an exogenous rate g_f:

$$y_f = y_{f,-1} \cdot (1 + g_f) \tag{87}$$

Foreign sector and Redundant equation

The nominal exchange rate is fixed. Any trade surplus or deficit is reflected in changes in foreign reserves:

$$hf = hf_{-1} + tb \tag{88}$$

where the trade balance is defined as exports minus imports:

$$tb = ex - im \tag{89}$$

The model closes with the redundant equation equating cash demand and supply by households:

$$hh = hs \tag{90}$$

Feature of the model and experiments

3 The Model

Several modifications to the original Godin (2014) and Sawyer and Passarella (2021) models were introduced such as:

i. *A JG with exogenous wg/w and exogenous employees and complete absorption of unemployed (Scenario 2)*;

ii. *A JG that improves the energy productivity alongside the reduction in energy demand (Scenario 4)*;

iii. *The reduction in the parameters of energy consumption is driven by how many public resources are committed (Scenarios 4 and 5)*;

Feature of the model and experiments

iv. *Two scenarios with government expenditure is introduced in order to provide a comparison either with the normal JG and with the green JG (Scenarios 3 and 5)*;

v. *The endogenous component of government transfers is set to 0* (τ_5) ;

vi. *Endogenous government expenditure in the productive sectors is redistributed away from sector e and injected into sector k (Scenario 6)*;

vii. *The CB is always eager to support the government action via QE policies*;

viii. *Adaptive expectations are assumed* .

Scenarios

3 The Model

Hence, the new scenarios are the following (Scenario 1 is the baseline):

- **Scenario 2**: Minsky-like JG;
- **Scenario 3**: Government transfers to unemployed;
- **Scenario 4**: Green JG (Scenario 2 with Godin-like energy transition) ;
- **Scenario 5**: Government transfers to unemployed (as Scenario 3) with reduction in energy consumption and increase in energy productivity similar to Scenario 4 ;
- **Scenario 6**: Scenario 4 but with redistribution of government expenditure.

Recall that all the experiments are introduced as shocks to the baseline model at time 60 (out of 100 periods).

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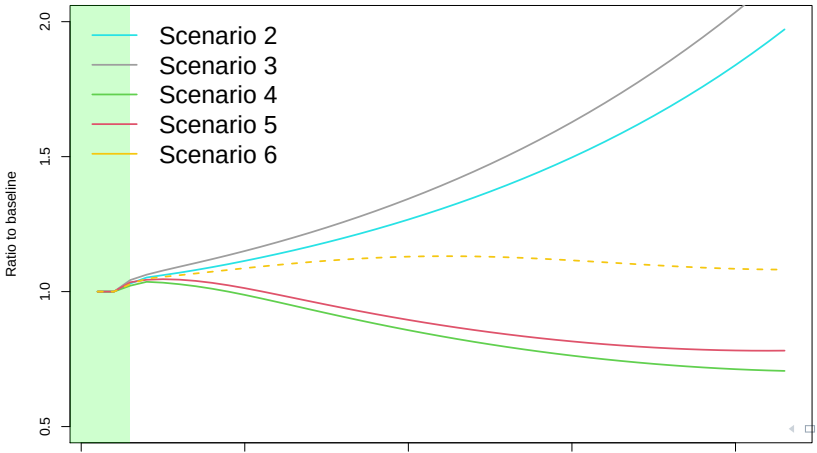
4 Results

Results

4 Results

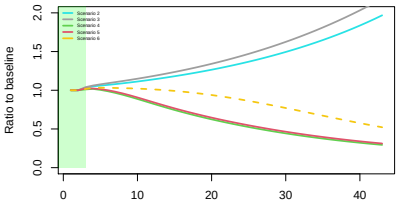
iv) Output under alternative scenarios



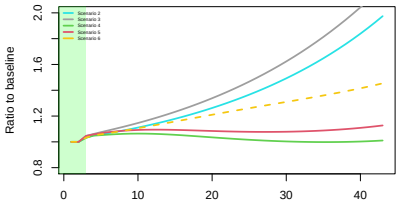
Results

4 Results

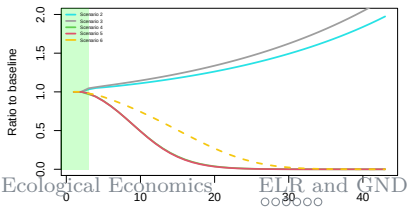
v) Output E sector under alternative scenarios



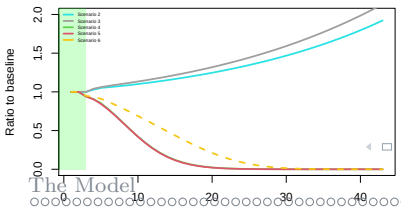
vi) Consumption under alternative scenarios



vii) Consumption Energy (Households)



viii) Consumption Energy (Government) under alternative scenarios



Results

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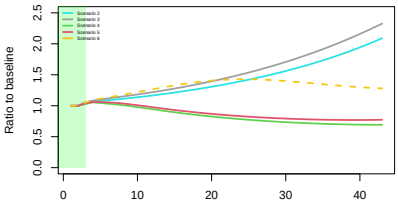
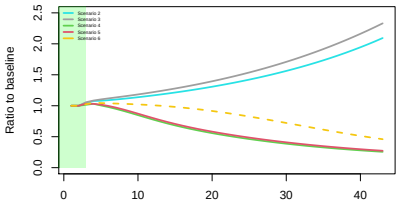
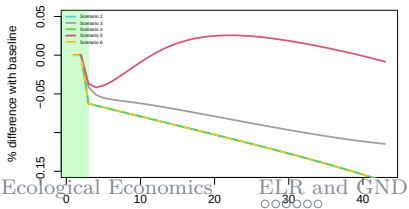
ix) Investment under alternative scenarios



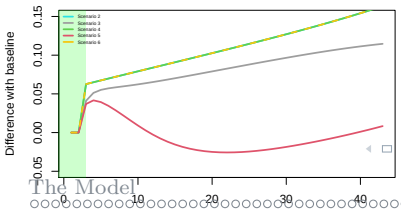
x) Energy Investment under alternative scenarios



xi) Unemployment rate under alternative scenarios



xii) Employment rate under alternative scenarios



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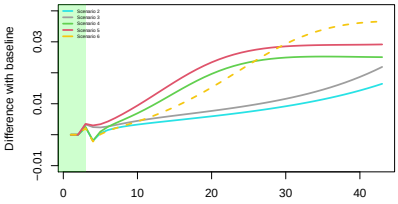
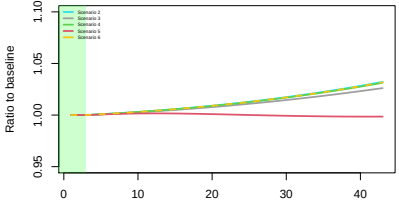
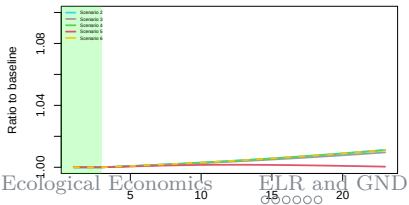
xiii) Deficit to GDP ratio under alternative scenarios



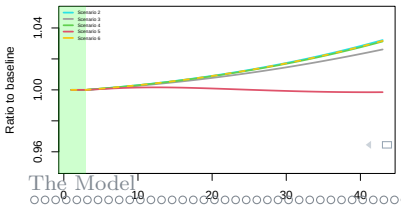
xiv) Price of private goods under alternative scenarios (long run)



xv) Prices of private goods under alternative scenarios (short run)



xvi) Average Nominal Wage in all the productive sectors



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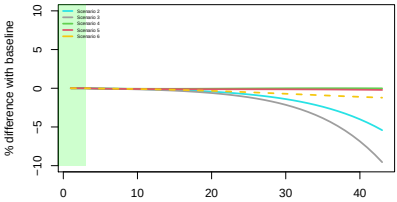
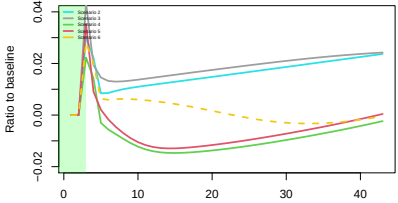
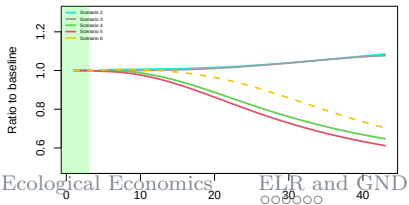
xvii) Trade Balance under alternative scenarios



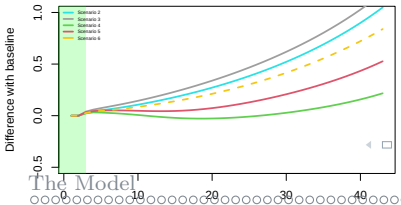
xviii) Output growth under alternative scenarios



xix) Bills held by CB under alternative scenarios



xx) Debt to GDP ratio under alternative scenarios



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5 Discussion

Discussion

5 Discussion

- Reducing energy consumption does come with a *cost for the economy*;
- The main difference with the "standard" (Scenarios 2 and 3) and the "green" measures (Scenarios 4 and 5) is that, in spite of the stimulus, total output tends to be lower than the baseline as a result of the *endogenous reduction* in the parameters of households and government energy consumption;
- To prevent this, it is necessary to *redistribute instead of reduce* total government spending, thereby maintaining a certain target government expenditure on GDP;

Discussion

5 Discussion

- Cash transfer or some employment guarantee scheme can't do the job alone, but they require *expenditure in the productive sectors*;
- The main advantage of the JG over cash transfers is that it *prevents job losses* when energy transition is undertaken;
- Interestingly, the *trade balance deteriorates only marginally* in Scenario 6, while in all the other cases it stays close to 0 (goes negative) when total output is lower (higher) in the steady state.

Discussion

5 Discussion

Table: Wrap-up of the results (long-run)

	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Output	+	+	−	−	+
Output e	+	+	−	−	−
Investment	+	+	−	−	+
Wages	+	+	+	−	+
Unemployment	−	−	−	0	−
Deficit/GDP ratio	+	+	+	+	+
Debt/GDP Ratio	+	+	+	+	+
Trade Balance	−	−	0	0	−
Output Growth	+	+	0	0	0

Scenario 2

5 Discussion

Closely resembling Minsky (1965, 1968, 1994), the wage paid in this program is set below the current prevailing wage in the private sector, while workers who do not find a job in the private industry are hired in the JG workforce. Part of the scheme is assumed to be financed by tariffs levied on households.

$$nn = ns - nd \tag{91}$$

$$wg = \rho_g * w \tag{92}$$

$$ng = ng_{-1} + \gamma_g * (nn - ng_{-1}) \, , \gamma_g = 1 \tag{93}$$

$$wbg = wg * ng \tag{94}$$

$$cgov = min(alpha_g * c, wbg) \tag{95}$$

Scenario 3

5 Discussion

Under this scenario, unemployment benefits are distributed to all workers that do not find a job in the private sector.

$$\tau_4 = nn * \ wg \tag{96}$$

$$\tau_5 = 0 \tag{97}$$

Scenario 4

5 Discussion

In addition to the equation in Scenario 2, this experiment introduces the loss function for both households and government energy expenditure and the gain function for energy productivity in the private sector. The intuition behind this choice is that the Employment Guarantee scheme target energy efficiency, as it reduces the need of energy by both the private and the public sector.

$$\sigma_2 = (1 - wbg * \zeta) * \sigma_2 \tag{98}$$

$$\sigma_3 = (1 - wbg * \zeta) * \sigma_3 \tag{99}$$

$$pre = (1 + wbg * \zeta) * pre \tag{100}$$

Scenario 5

5 Discussion

$$\sigma_2 = (1 - \tau_4 * \zeta) * \sigma_2 \tag{101}$$

$$\sigma_3 = (1 - \tau_4 * \zeta) * \sigma_3 \tag{102}$$

$$pre = (1 + \tau_4 * \zeta) * pre \tag{103}$$

Scenario 6

5 Discussion

In this scenario, government expenditure in the k sector depends also upon the endogenous shift of expenditure from the e sector.

$$c_g k = \sigma_1 * (y_{k,-1}) + (0.1 - \sigma_2) * (y_{e,-1}) \tag{104}$$

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Q&A

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