**Philia 1.0. An ecological PK-SFC model.**

[**https://github.com/Philia-ecs/Philia1.0**](https://github.com/Philia-ecs/Philia1.0)

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## Accounting structure

As shown in table A1, the model comprises seven institutional sectors: a household sector (divided into working and rentier households), a government sector (divided into the Treasury), state-owned firms, social firms consisting of cooperatives owned by working households, a sector of listed non-financial corporations, a banking sector, a Central Bank, and a sector of investment funds comprising unlisted intermediaries (such as institutional investors, asset management companies, and insurance companies)

This matrix depicts a three-tiered productive structure. State-owned firms are operated by the government and their budget constraint is merged with that of the Treasury. Social firms are owned by working households and financially constrained as they only have access to retained earnings and bank loans. Listed firms are owned by investment funds and finance their investment with their retained earnings and by issuing the full range of debt market instruments (bank loans, corporate bonds, commercial paper) as well as equities.

Two categories of households are featured, with segmented access to financial markets. Working households earn wages and redistributed surpluses from social firms and keep their unspent disposable income as cash and savings deposits. Rentier households, on the other hand, earn financial income only, and keep their unspent disposable income as cash, savings deposits and investment fund shares.

Financial sector instruments include high-powered money (reserve assets and cash), advance loans from the Central Bank, savings account deposits, loans, bonds, commercial paper, equities, investment fund shares, Treasuries. The Central Bank operates a refinancing desk, a deposit facility, and holds a repurchased asset portfolio. Investment funds hold the banking sector’s equity and listed corporations’ equity (in addition to Treasuries and banking deposits) and distribute their entire profits to rentier households.

Finally, the model includes a full green taxonomy for all debt instruments, productive assets, and investment decisions. However, these are not reported in the matrix for the sake of clarity.

**Table A1 Simplified transaction matrix**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Households** | | **Treasury** | **State-owed firms** | | **Social firms** | | **Listed firms** | | **Banks** | | **Central Bank** | | **Investment funds** | |
|  | *Working* | *Rentiers* |  | | | | | | | | | | | | |
|  |  |  |  | Current | Capital | Current | Capital | Current | Capital | Current | Capital | Current | Capital | Current | Capital |
| Final consumption |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Public expenditure |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Taxes |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Investment |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Depreciation |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Wages |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Entrepreneurial profits |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Bank profits |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Central bank profits |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Investment fund profits |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| *Interest paid on* : |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Central bank refinancing |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Private debt instruments |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Bank deposits |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Central bank portfolio |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Mandatory reserves |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Excess reserves |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Treasuries |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Δ STOCKS |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Central bank loans |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Private debt instruments |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Bank deposits |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Reserve currency |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Equities |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Investment fund shares |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Central bank asset purchases (when active) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Treasuries |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Bank equity |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Central bank equity |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Note: To make reading easier, this matrix consolidates bank loans, private bonds and commercial paper (and their respective interest rates) into a single ‘private debt instruments’ category. For the same reason, it does not show either the green taxonomy which applies to both productive and financial assets.

**Figure A1 A circuit view** **of Philia 1.0’s economic block**

Une image contenant ligne, diagramme

Le contenu généré par l’IA peut être incorrect.

Note: this circuit figure is constructed following the guidelines put forth by Poulon (2015). Poles H, B, T, E, CB and IF refer to the model’s aggregate institutional sectors: households, banks, the Treasury, enterprises, the Central Bank and investment funds, respectively. The origin of each arrow indicates a resource use (a - sign in table A1) and the endpoint indicates a source of resource (a + sign in table A1). Poulon (2015) suggests that circuit views should only represent net financing flows. Accordingly, superscripts indicate that the reverse flow of annual interest payments has been subtracted from the corresponding variable.

**Figure A2 Ecosystemic retroaction**

Une image contenant cercle, diagramme, ligne, croquis

Le contenu généré par l’IA peut être incorrect.

Table A2 describes the model’s physical flow matrix, which is based on Carnevali et.al (2021). This matrix ensures that neither energy nor matter is created or destroyed during production (first law of thermodynamics). In addition, energy consumption dissipates in the form of heat (second law or ‘entropy’).

The first column contains the yearly material balance of the economy (in gigatons (Gt)). It equates material inputs (extracted carbon mass ), non-renewable energy and oxygen ) with annual material outputs (industrial CO2emissions , waste), and change in the socio-economic stock ). The second column shows the yearly energy balance (in Exajoules (Ej)). It equates annual energy inputs (renewable and non-renewable reserves) with entropy ().

**Table A2.** Material and energy balance

|  |  |  |
| --- | --- | --- |
|  | Material reserves (Gt) | Energy reserves (Ej) |
| Inputs |  |  |
| Material extraction |  |  |
| Renewable energy |  |  |
| Non-renewable energy |  |  |
| Oxygen used in combustion |  |  |
| Outputs |  |  |
| Industrial CO2 emissions |  |  |
| Waste |  |  |
| Dissipated energy (entropy) |  |  |
| Variation of the socio-economic stock |  |  |
| **Total** | **0** | **0** |

Note: Additions are indicated by a (+) sign. Reductions are indicated by a (-) sign.

Table A3 is also based on Carnevali (2021) and shows the physical stocks and flows matrix. It traces the joint evolution of the stock of physical reserves , non-renewable energy reserves, atmospheric CO2 concentration (, and the socio-economic stock. This matrix draws an important distinction between *resources* and *reserves*. Reserves are stocks of material and non-renewable energy resources that have been extracted and are available for production. The first row of the matrix contains the reserves inherited from the previous period. The last row displays the stocks available at the end of the annual production process.

**Table A3.** Stocks and physical flows matrix

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Material reserves | Non-renewable energy reserves | Atmospheric concentration of C02 | Socio-economic stock |
| Initial stock |  |  |  |  |
| Conversion of resources to reserves |  |  |  |  |
| CO2 emissions |  |  |  |  |
| Production of material goods |  |  |  |  |
| Extraction/use of material and energy |  |  |  |  |
| Net transfer to the oceans and biosphere |  |  |  |  |
| Destruction of the socio-economic stock |  |  |  |  |
| Final stock |  |  |  |  |

Note: Additions are indicated by a (+) sign. Reductions are indicated by a (-) sign.

## Writing conventions

Real sector transaction flow variables are denoted by a capital letter. In the financial sector, a lower-case letter denotes a flow variable, and an upper-case letter denotes a stock variable. Regarding subscripts, the first subscript reads *s* or *d* to indicate whether the corresponding variable is supply or demand-side. The second subscript identifies the sector to which the variable belongs: the household sector (*h*), worker households (*w*), rentier households (*r*), social firms (*c*), listed firms (*k*), banks (*bk*), investment funds (*if*), the central bank (*cbk*), and the public sector (*p*). The third subscript, when present, applies a green (*g*) or brown (*b*) taxonomy to the variable. A (-1) subscript indicates a lagged variable. A variable which is preceded by the sign is first-differenced.

|  |  |  |  |
| --- | --- | --- | --- |
| **Subscripts** | | | |
| Symbol | Description | Symbol | Description |
|  | social firms (coop firms) |  | ecosystem |
|  | listed corporations |  | savings account |
|  | public sector (government) |  | bank loans |
|  | working households |  | corporate bonds |
|  | rentier households |  | commercial papers |
|  | households |  | government bonds |
|  | investment funds |  | deposit facility |
|  | banks |  | mandatory reserve |
|  | central bank |  | excess |
|  | demand |  | quantitative easing |
|  | supply |  | equities |
|  | green |  | lender risk |
|  | brown |  | wage bill |
|  | previous period value |  | firms |

|  |  |  |  |
| --- | --- | --- | --- |
| **Superscripts** | | | |
| Symbol | Description | Symbol | Description |
|  | ex-ante |  | target |
|  | expected, ex-post |  | maximum |
|  | real value |  |  |

|  |  |  |  |
| --- | --- | --- | --- |
| **Variables and Parameters** | | | |
| Symbol | Description | Symbol | Description |
|  | **Macroeoconomic income** |  |  |
|  | nominal GDP |  | workers negotiation power |
|  | investment |  | firms product market power |
|  | consumption |  | wage share |
|  | inflation rate |  | ecosystem inflation impact |
|  | general price level |  | stock of physical capital assets |
|  | cumulative ecosystem inflation |  | depreciation expenditures |
|  | **Households** |  |  |
|  | financial wealth |  | wealth share in savings deposits |
|  | disposable income |  | deposit rate factor |
|  | minimum consumption |  | transaction rate factor |
|  | consumption coefficient from disposable income |  | investment funds shares |
|  | consumption coefficient from financial wealth |  | rentier assets allocation factors |
|  | eco-systemic destruction impact on consumption from wealth |  | ecosystemic events impact on liquidity preference |
|  | share of total consumption |  | wage bill |
|  | savings account |  | share of total wages |
|  | **Enterprises (Social and Listed Corp.)** |  |  |
|  | profit |  | adaptation parameter to the eco-systemic damage |
|  | retention rate (self-financing rate) |  | stock of bank loans |
|  | dividend |  | stock of corporate bonds |
|  | retained earnings |  | stock of commercial papers |
|  | obsolescence rate of productive capital assets |  | annual credit flow |
|  | surplus accelerator factor on investment |  | annual flow of corporate bonds issues |
|  | debt modulator factor on investment |  | annual flow of commercial papers issues |
|  | partial adjustment of capital stock |  | external financing |
|  | capital stock target parameter |  | stock of private sector debt |
|  | proportion of total gross investment |  | stock of equities |
|  | relative cost of debt (brown vs green) |  | annual flow of equities issues |

|  |  |  |  |
| --- | --- | --- | --- |
| **Variables and Parameters** | | | |
| Symbol | Description | Symbol | Description |
|  | **Banks** |  |  |
|  | debt term structure parameters |  | stock of Central Bank reserve loan |
|  | lender credit risk score |  | total assets |
|  | banks collateral requirements (social firm) |  | total liabilities |
|  | coefficient on leverage level |  | risky weighted assets |
|  | coefficient on economic growth |  | risk weight |
|  | coefficient on cost of refinancing |  | capital adequacy ratio |
|  | banks internalization of eco-systemic damage |  | liquidity coverage ratio |
|  | flow of credit granted to firms |  | households’ liquidity preference |
|  | mandatory reserve requirement |  | households’ preference for liquidity |
|  | **Central Bank** |  |  |
|  | stock of Central Bank’s assets |  | high powered money (cash and reserve assets) |
|  | flow of quantitative easing issues |  | flow of high powered money |
|  | **Rates and Assets** |  |  |
|  | interest rate |  | mark-up to the refinancing rate |
|  | brown to green market spread |  | assets rate of return |
|  | greenium modulation parameter |  | capital gains |
|  | baseline greenium parameter |  | financial asset price |
|  | liquidity risk premium |  | secondary market parameters |
|  | liquidity risk premium |  | adaptive expectation parameters (capital gains) |
|  | **Public sector** |  |  |
|  | budget balance |  | taxes |
|  | government spending |  | income tax rate |
|  | share of government spending in social firms |  | stock of government bonds |
|  | target growth rate of the total productive capital |  | annual flow of government bonds issues |
|  | fraction of the total demand for capital goods |  |  |

|  |  |  |  |
| --- | --- | --- | --- |
| **Variables and Parameters** | | | |
| Symbol | Description | Symbol | Description |
|  | **Material** |  |  |
|  | socio-economic stock |  | recycled socio-economic stock |
|  | discarded socioeconomic stock |  | proportion of the discarded socio-economic stock that is recycled |
|  | share of socio-economic stock |  | annual material waste emissions |
|  | share of material production in GDP |  | annual material reserves |
|  | material production (Annual matter used) |  | annual material resources |
|  | share of material production |  | conversion of natural reserves into material stocks |
|  | Annual matter extraction |  | conversion of material resources |
|  | **Energy** |  |  |
|  | annual variations of the stock of non-renewable energy |  | energy required for the production |
|  | conversion of energy resources into reserves |  | renewable energy |
|  | conversion of energy resources |  | conversion of production to energy coefficient |
|  | energy reserves |  | dissipated energy |
|  | non-renewable energy |  |  |
|  | **Emissions** |  |  |
|  | annual CO2 emissions |  | initial value of CO2 emissions |
|  | land emissions |  | oxygen stock |
|  | land emissions declining rate |  | carbon mass |
|  | industrial emissions |  | conversion coefficient of carbon in CO2 |
|  | **Carbon cycle** |  |  |
|  | radiative forcing |  | atmospheric temperature adjustment coefficient |
|  | increase factor of radiative forcing |  | atmosphere heat loss transfer coefficient from lower ocean |
|  | atmospheric concentration of CO2 |  | lower ocean heat gain transfer coefficient from atmosphere |
|  | pre-industrial atmospheric concentration of CO2 |  | climate sensitivity |
|  | radiative forcing due to non-CO2 greenhouse gases |  | biosphere reservoir |
|  | increase in radiative forcing due to non-CO2 greenhouse gases |  | ocean reservoir |
|  | atmospheric temperature |  | CO2 transfer coefficient |
|  | oceanic temperature |  |  |
|  | **Eco-efficiency** |  |  |
|  | carbon intensity of non-renewable energy |  | share of renewable energy |
|  | proportion of energy required for GDP |  | eco-efficiency technological capacities |
|  | **Ecosystem retroaction** |  |  |
|  | depletion of material resource |  | climate-related damage |
|  | depletion of material reserves |  | damage coefficient |

## Macroeconomic income (Module 1)

#### Nominal GDP

Nominal GDP (Y) is the sum of expenditures on goods and services, including consumption investment and government spending (equation 1.1). Investment is the sum of listed corporations’ investment , social firms’ investment and public sector firms’ investment (equation (1.2)). Macroeconomic final consumption ) is the sum of working and rentier households consumption expenditures (equation (1.03)).

|  |  |
| --- | --- |
|  | (1.01) |
|  | (1.02) |
|  | (1.03) |

#### Inflation and real GDP

Following Setterfield (2023), we define the actual inflation rate as the sum of price inflation and a parameter (equation (1.10)). The latter captures the persistent effects of supply shocks (equations (1.11)). caused by the depletion of energy and material resources ( and , respectively) and climate induced damage (equation (1.12)).

|  |  |
| --- | --- |
|  | (1.10) |
|  | (1.11) |
|  | (1.12) |

Inflation is modelled based on simplified form of the canonical Kaleckian conficting claims of inflation developed in Rowthorn (1977), exposed mathematically in Dutt (1988, 1992), and used in recent empirical literature (Setterfield, 2023; Charles, 2024; Charles, Dallery and Marie, 2024) as well as surveys (Hein, 2024). We begin with the following simplified equations:

where is the rate of growth of nominal wages, is the target wage share of workers, is the actual wage share, is the rate of price inflation intended by firms, is the target wage share of firms, is the realized (actual) rate of inflation. The parameters and denote the relative power of workers in the wage bargain, and the relative power of firms in product markets, respectively. At the end of the bargaining process , which yields the equations (1.13) and (1.14):

|  |  |
| --- | --- |
|  | (1.13) |
|  | (1.14) |

In recent decades, trade unions’ influence on wage determination has decreased, due both to neoliberal policies and to the individualization of wage contracting. Inflation thus erodes trade union’s target wage share and their negotiating power (1.15) and (1.16). By contrast, firms’ wage target (and negotiating power in product markets *)* are unchanged.

|  |  |
| --- | --- |
|  | (1.15) |
|  | (1.16) |

The annual inflation rate ) yields the macroeconomic price index (equation (1.17)) and real GDP (1.18).

|  |  |
| --- | --- |
|  | (1.17) |
|  | (1.18) |

#### Productive capital assets

Total productive capital assets can be broken down by sector and according to the green taxonomy. The total stock of productive assets () is the sum of productive assets held by listed corporations , social firms and public sector firms ( (equation (1.20)). Macroeconomic depreciation expenditure () is spent by listed firms , social firms and public sector firms (1.21). The stock of brown productive capital assets is owned by listed corporations , social firms and public sector firms (1.22). The macroeconomic stock of green capital is obtained with an accounting criterion (1.23).

|  |  |
| --- | --- |
|  | (1.20) |
|  | (1.21) |
|  | (1.22) |
|  | (1.23) |

## Households (Module 2)

#### Nominal and real financial wealth

Macroeconomic nominal financial wealth ) is equal to its lagged value, plus the gap between macroeconomic disposable income (+ ) and macroeconomic consumption ( (2.01). A similar method determines working households’ nominal financial wealth (2.02). The nominal financial wealth of rentier households is determined with an accounting criterion (2.03).

|  |  |
| --- | --- |
|  | (2.01) |
|  | (2.02) |
|  | (2.03) |

Macroeconomic real financial wealth , working household’s real financial wealth and rentier households’ real financial wealth are obtained by dividing their nominal values by the macroeconomic price index ) ((2.04) to (2.06)).

|  |  |
| --- | --- |
|  | (2.04) |
|  | (2.05) |
|  | (2.06) |

### CONSUMPTION

#### Nominal and real household consumption

Nominal working household consumption depends on a minimum threshold (), nominal annual disposable income (parameter ) and lagged financial wealth (parameter ) (equation (2.10)). Rentier households, however, do not draw from their stock of financial capital for consumption purposes (equation (2.11)).

|  |  |
| --- | --- |
|  | (2.10) |
|  | (2.11) |

Households react to ecosystem-caused destructions building up precautionary savings, which reduces consumption. Household’s propensity to draw on their stock of wealth ( decreases with ecosystemic shocks (2.12).

|  |  |
| --- | --- |
|  | (2.12) |

Real consumption and is a ratio between nominal consumption and the annual macroeconomic price index (equations (2.13) and (2.14)).

|  |  |
| --- | --- |
|  | (2.13) |
|  | (2.14) |

#### Allocation of consumption

Nominal consumption expenditures are directed towards the social firm sector and the public sector as fixed proportions (( and (, respectively) of total nominal consumption ) ((2.15) and (2.16)). Consumption expenditures allocated to the listed corporation sector is determined with an accounting criterion (2.17).

|  |  |
| --- | --- |
|  | (2.15) |
|  | (2.16) |
|  | (2.17) |

### SAVING

#### Households' portfolio choice

Working households and rentier households have access to different financial assets. The only financial assets held by working households are cash and savings deposits. Working households wish to hold a baseline proportion of their wealth as savings deposits and another as cash (. This baseline proportion is modulated by two elements: the deposit rate (through parameter ) and the transaction motive of money demand (through parameter ). Following Godley and Lavoie (2012), we set (2.20) (7.1).

|  |  |
| --- | --- |
|  | (2.20) |

Working households’ demand for cash is obtained with an accounting criterion (2.21).

|  |  |
| --- | --- |
|  | (2.21) |

The portfolio decision of rentier households is slightly more complex: in addition to cash and deposit accounts, rentier households can also purchase shares in investment funds . Their portfolio holdings depend on deposit rates , expected return on investment funds shares (), and the transaction motive (2.22).

|  |  |
| --- | --- |
|  | (2.22) |

The elements contained in the first three columns of the above (4x3) parameter matrix are set so as to respect the two vertical constraints (; ); as well as the symmetry constraints (Godley and Lavoie, 2012).

Adverse ecosystemic events affect portfolio allocations of rentier households by increasing their liquidity preference. Observing increased eco-systemic destructions () lead rentier households to hold a larger share of their wealth as cash and savings deposits. This is reflected by the last column of the parameter matrix, which states that . In addition, increases with adverse ecosystemic events, in proportion to a parameter (2.23).

|  |  |
| --- | --- |
|  | (2.23) |

Instead of using the third line of matrix (2.22), we employ an accounting criterion. Rentier households’ liquid holdings ( equal their financial wealth net of savings deposits and portfolio of investment funds shares (2.24).

|  |  |
| --- | --- |
|  | (2.24) |

Macroeconomic cash holdings ( is obtained with an accounting criterion (2.25). Total household demand for banking deposits is the sum of rentier and working households demand (2.26).

|  |  |
| --- | --- |
|  | (2.25) |
|  | (2.26) |

### INCOME

#### Nominal and real household disposable income

Working and rentier households earn different types of income. Working households’ nominal disposable income is the sum of the wage bill, redistributed surpluses of social firms , net of self-financing retention ratio ), and the interest earned on the lagged stock of bank deposits , minus the income tax (2.30).

|  |  |
| --- | --- |
|  | (2.30) |

Rentier households’ nominal income is the sum of the dividend payments of investment funds , interest earned on lagged bank deposits , minus the income tax (2.31).

|  |  |
| --- | --- |
|  | (2.31) |

Real disposable household income is calculated by adjusting both nominal disposable income and nominal financial wealth ) (2.32) and (2.33)[[1]](#footnote-2).

|  |  |
| --- | --- |
|  | (2.32) |
|  | (2.33) |

#### The wage bill and allocation of wages

The nominal wage bill equals the product of the lagged wage share and nominal GDP ) (equation (2.34)). It is split in the listed firm, public firm and social firm sector so that (equations (2.35) to (2.37)).

|  |  |
| --- | --- |
|  | (2.34) |
|  | (2.35) |
|  | (2.36) |
|  | (2.37) |

## Social enterprises (Module 3)

#### Surplus

Social firms are cooperatives held by working households. Their financial surplus ( is derived from their current account. It equates their annual turnover (final consumption , investment expenditure , plus a fixed proportion of central government spending , net of the wage bill (, depreciation expenditure (, interest paid on the stock of ‘brown’ and ‘green’ bank loans ( and , respectively), and tax payments (at rate ) (3.01).

|  |  |
| --- | --- |
|  | (3.01) |

### INVESTMENT (ASSETS)

#### Total investment demand

Social firms’ productive assets are divided into a green and a brown component (3.10).

|  |  |
| --- | --- |
|  | (3.10) |

Depreciation expenditures depends on the rate of obsolescence of productive capital assets. The latter is a fixed proportion of lagged brown and green ) productive capital assets ((3.11) to (3.13)).

|  |  |
| --- | --- |
|  | (3.11) |
|  | (3.12) |
|  | (3.13) |

#### Productive assets

Social firm’s stock of green and brown productive assets and , respectively) is the sum of their lagged value and new investment expenses , respectively), net of depreciation allowances and , respectively) ((3.14) and (3.15)).

|  |  |
| --- | --- |
|  | (3.14) |
|  | (3.15) |

Social firms’ demand for investment follows the partial accelerator model (Mazier, 2020). In contrast to listed firms, social firms have limited market power and access to information. Their expectations are hence formed based on micro-level variables. The capital stock target increases with the lagged surplus rate () (according to parameter ), this effect being modulated by the lagged debt to capital asset ratio (according to a parameter ) (3.16).

|  |  |
| --- | --- |
|  | (3.16) |

Social firms’ gross investment demand has two components. The first is a partial adjustment to the gap between the capital stock target and the lagged capital stock . The second component consists in depreciation expenditures ()(3.17).

|  |  |
| --- | --- |
|  | (3.17) |

#### Green structure of investment demand

The green structure of investment demand depends on three factors: sectoral adaptation efforts, a ‘Mazzucato effect’ (2018) linked to green public investment, and the relative cost of external finance. Social firms’ baseline demand for green investment is a proportion of total gross investment demand (through parameter ). This baseline demand is modulated by adaptation efforts to ecosystemic destructions , by increases in public green investment programs , and by the brown interest rate spread ( (through a parameter ) ((3.17) and (3.18)).

|  |  |
| --- | --- |
|  | (3.18) |

Social firm’s demand for brown investment is obtained with an accounting criterion (equation (3.19)).

|  |  |
| --- | --- |
|  | (3.19) |

#### Investment spending

Brown investment expenditures is the sum of new brown loans obtained from banks ( and self-financing of brown projects (). Green investment is modeled along ((3.20) and (3.21)).

|  |  |
| --- | --- |
|  | (3.20) |
|  | (3.21) |

The above two equations distinguish the *effective* loan supplygranted by the banking sector and from the *notional*[[2]](#footnote-3) demand for loans and originating from entrepreneurial expectations. Given the fact that social firms do not issue equity, the distance between the notional demand and effective loan supply is a measure of investment rationing.

Total investment expenditure is the sum of its green and brown components (3.22).

|  |  |
| --- | --- |
|  | (3.22) |

### FINANCING (LIABILITIES)

#### Financial structure

Bank loans are the only form of external finance available to social firms. The demand for external finance follows the pecking order theory of corporate financing (Myers and Majluf, 1984). The demand for green ( and brown credit equals green and brown investment demand, minus an exogenous self-financing rate factored by surpluses ((3.30) and (3.31)). The total demand for credit is obtained with an accounting criterion (3.22).

|  |  |
| --- | --- |
|  | (3.30) |
|  | (3.31) |
|  | (3.32) |

#### Financial liabilities

The effective loan supply is the sum of brown and green credit granted by the banking sector (3.33). Stocks of green , brown loans equal their past values, plus corresponding annual flows ((3.34) and (3.35)). The total debt is given by an accounting criterion (3.36).

|  |  |
| --- | --- |
|  | (3.33) |
|  | (3.34) |
|  | (3.35) |
|  | (3.36) |

## Listed firms (Module 4)

#### Profits and dividend payments

‘Shareholder value maximization’ has become the dominant governance corporate paradigm under neoliberalism (Duménil and Lévy, 2013). Equation (18) to (21) thus describe a finance-led governance for listed firms: dividend payments to outside shareholders take priority over the financing of new investment projects.

The gross profits of listed firms equals their annual turnover (i.e. the sum of final consumption , investment expenditure , a fixed proportion of government spending , net of the wage bill ( depreciation expenditure (), and external financing costs. The latter include interest paid on ‘brown’ and ‘green’ bank loans (( and , respectively), coupon payments on ‘brown’ and ‘green’ corporate bonds (( and respectively), interest on ‘brown’ and ‘green’ corporate paper ( and , respectively) and dividend payments to external shareholders. Net profits () equal gross profits, net of taxes . Subtracting dividend payment (at rate ( yields listed firms’ self-financing capacity (4.01).

|  |  |
| --- | --- |
|  | (4.01) |

The annual flow of dividend payment and the demand for dividend payments are shown in (4.02) and (4.03). Listed firms are controlled by investment funds, which set an annual dividend payout ratio expressed in nominal terms.

|  |  |
| --- | --- |
|  | (4.02) |
|  | (4.03) |

The retained earnings allocated to the financing of productive investments are shown in (4.04).

|  |  |
| --- | --- |
|  | (4.04) |

### INVESTMENT (ASSETS)

#### Total investment demand

Brown capital assets are obtained by subtracting depreciation allowances and adding new brown investment to the lagged stock of brown capital (4.11). A similar process is used to determine the stock of green capital assets (4.12). The total productive capital stock is obtained with an accounting criterion (4.10).

|  |  |
| --- | --- |
|  | (4.10) |
|  | (4.11) |
|  | (4.12) |

Depreciation and amortization expenditures () are equal to the lagged capital stock, factored by a homogenous rate of capital obsolescence (0) ((4.13) to (4.15)).

|  |  |
| --- | --- |
|  | (4.13) |
|  | (4.14) |
|  | (4.15) |

In contrast to social businesses, listed corporations have a significant market power and access to information. They hence make productive bets based on global macroeconomic prospects. Their productive capital target is set as a proportion () of nominal GDP (equation (4.16)).

|  |  |
| --- | --- |
|  | (4.16) |

Investment demand has two components: the first is a partial adjustment to the distance between the capital target and the lagged capital stock . The second component consists in the depreciation expenditures () (4.17).

|  |  |
| --- | --- |
|  | (4.17) |

#### Green structure of investment demand

The baseline demand for green investment is a proportion of total gross investment demand (through a parameter ). This proportion increases with ecosystemic destruction which generates an adaptive behavior The scaling up of green investment by the public sector firms leads listed firms to increase the proportion of green investment in their total investment. This proportion increases with the relative cost of brown and green loans ( (through a parameter ) (equation (4.18)).

|  |  |
| --- | --- |
|  | (4.18) |

The demand for brown investment is obtained with an accounting criterion (4.19).

|  |  |
| --- | --- |
|  | (4.19) |

#### Investment spending

Investment expenditure is the sum of brown and green investment expenditure ( and , respectively) (4.22). Brown and green investment expenditure are the sum of corporate debt , self-financing , and equities issues ((4.20) and (4.21)).

|  |  |
| --- | --- |
|  | (4.20) |
|  | (4.21) |
|  | (4.22) |

### FINANCING (LIABILITIES)

#### Investment financing

In contrast to social firms, listed firms have access to the full range of debt instruments and can also issue equity to finance their investment program. Following the pecking order theory of corporate finance (Myers and Maljuf, 1984), listed corporations prioritize retained earnings to finance their investment expenditure. Then, they turn to the credit and the debt market, and issue new equities in last resort to fill the finance gap.

This process is reflected in equations (4.30) to (4.33). Equations (4.30) gives the notional demand for credit as the sum of ‘green’ and ‘brown’ demand components () and , respectively).

|  |  |
| --- | --- |
|  | (4.30) |

In turn, the notional demand for green and brown credit is equal to gross investment demand ( and , respectively), net of depreciation expenditures ( and , respectively), and retained earnings ( and , respectively) ((4.31) and (4.32)).

|  |  |
| --- | --- |
|  | (4.31) |
|  | (4.32) |

Equity issues cover the distance between the notional demand for credit and the effective demand for credit (4.33). To the extent that sufficient demand for equity (i.e., ) listed firms’ investment is virtually unconstrained.

|  |  |
| --- | --- |
|  | (4.33) |

#### Financial liabilities

New debt liabilities include green and brown commercial paper and , respectively), green and brown corporate bonds and , respectively) and green and brown loans and , respectively) ((4.34) to (4.39)). These flows, which permit to identify the breakdown of corporate debt, are driven by banking sector’s liquidity preference (hence the ‘*d*’ suffix on the right-hand term of each equation). The behavior of banks is discussed in section 9.

|  |  |
| --- | --- |
|  | (4.34) |
|  | (4.35) |
|  | (4.36) |
|  | (4.37) |
|  | (4.38) |
|  | (4.39) |

Stocks of financial liabilities include equities , total, brown and green corporate paper ( and , respectively), total, brown and green corporate bonds ( and , respectively), total brown and green loans and , respectively). These are recorded at their historical value and decomposed into a green and brown component. Each stock is equal to its lagged value, plus the annual flow ((4.40) to (4.49)).

|  |  |
| --- | --- |
|  | (4.40) |
|  | (4.41) |
|  | (4.42) |
|  | (4.43) |
|  | (4.44) |
|  | (4.45) |
|  | (4.46) |
|  | (4.47) |
|  | (4.48) |
|  | (4.49) |

Total debt is the sum of its brown and green components ( and , respectively) (4.50). Each components includes corporate paper ( and , respectively), corporate bonds (respectively) and loans and , respectively) ((4.51) and (4.52)).

|  |  |  |  |
| --- | --- | --- | --- |
|  | | | (4.50) |
|  | | | (4.51) |
|  | | | (4.52) |
|  |  | |

## Banks (Module 5)

#### Income statement

The income of the banking sector is the sum of the interest earned on Treasuries , brown and green loans to social firms ( and ), respectively), brown and green loans to listed firms ( and ), respectively), brown and green commercial paper ( and , respectively), brown and green corporate bonds ( and, respectively), required reserves holdings and excess reserves holdings .

As in the Eurozone, required reserves holdings are remunerated at the main refinancing rate , and excess reserves are remunerated at the deposit facility rate . Banks' expenses include interest paid out to depositors and to the Central Bank .

Banks’ profits are the difference between income and expenses (equation (5.01)). These profits are transferred to investments funds as dividends (5.02).

|  |  |
| --- | --- |
|  | (5.01) |
|  | (5.02) |

### INVESTMENT (ASSETS)

#### Quantitative easing

The outstanding stock of corporate debt, however, is not always entirely held by the banking sector. Consider for instance equation (5.20). It shows that the stock of brown corporate paper held by the banking sector is equal to listed corporations’ stock of brown corporate paper liabilities net of lagged brown corporate paper repurchases by the Central Bank . Stocks of green corporate paper , brown () and green bonds, and brown and green loans to listed firms, and brown and green loans to social firms are determined in the same way ((5.10) to (5.22)). The historical value of corporate paper (, corporate bonds and loans showing up in banks’ balance sheets is shown in (5.22), (5.19) and (5.16).

|  |  |
| --- | --- |
|  | (5.10) |
|  | (5.11) |
|  | (5.12) |
|  | (5.13) |
|  | (5.14) |
|  | (5.15) |
|  | (5.16) |
|  | (5.17) |
|  | (5.18) |
|  | (5.19) |
|  | (5.20) |
|  | (5.21) |
|  | (5.22) |

The outstanding stocks of green and brown loans ( and , respectively), total debt instruments , and the stock of debt instruments issued by listed firms have their counterpart not in the balance sheet of banks but in that of the issuing sector ((5.23) to (5.24)).

|  |  |
| --- | --- |
|  | (5.23) |

#### Debt structure

Following Le Héron and Mouakil (2008), the structure of listed firms’ brown and green debt ( and ) respectively) is driven by banks’ preference for liquidity. The latter depends on observed returns for green and brown bonds () and ), loan portfolios ( and ) and interest rates on corporate paper ( and ) ((5.25) and (5.26)).

|  |  |
| --- | --- |
|  | (5.25) |
|  | (5.26) |

The parameters of the matrix respect both *vertical* (; ) and *symmetry* constraints: (Godley and Lavoie, 2012). We replace the last line of the above matrices with an accounting criteria ((5.27) and (5.28)).

|  |  |
| --- | --- |
|  | (5.27) |
|  | (5.28) |

Equations (5.29), (5.30) and (5.31) give the annual flows of corporate loans , corporate bonds and corporate paper .

|  |  |
| --- | --- |
|  | (5.29) |
|  | (5.30) |
|  | (5.31) |

#### Banking credit

The effective supply of credit is determined based on the post-Keynesian principle of increasing risk. Banks look at the financial position of the loan applicant, the greenness of the investment project, and consider their own expectations about the future state of the economy.

Banks apply different credit scores for listed firms and social firms. Banks and listed firms are indirectly owned by rentier households through investment funds. Banks are more eager to open credit lines to listed firms than to social businesses.

Banks apply strict collateral requirements to social firms. Credit to social firms (and ) is zero when banks consider these firms have excessive leverage, i.e. when stock of exceeds a given proportion of their lagged stock of productive capital .

Banks then apply a sector-specific and a taxonomy-specific credit risk score ( and , respectively) to borrowers that passing the collateral condition ((5.32) and (5.33)).

|  |  |
| --- | --- |
|  | (5.32) |
|  | (5.33) |

Banks, however, do not screen listed firms for collateral. The effective credit supply (( and () depends solely on sector-specific and a taxonomy-specific scores and , respectively) ((5.34) and (5.35)).

|  |  |
| --- | --- |
|  | (5.34) |
|  | (5.35) |

Lending risk scores for both types of borrowers ( and ) increase with leverage ( and, respectively), decrease with ~~increase~~ with banks’ expectations (linked to observed economic growth ) , and increase the Central Bank’s main refinancing operations rate ((5.36) and (5.37)).

|  |  |
| --- | --- |
|  | (5.36) |
|  | (5.37) |

Lending risk reflect a green taxonomy. Brown lending risk equals green lending risk, plus a risk premium which increases with eco-systemic damages ), through a parameter ((5.38) and (5.39)). By internalizing the costs of ecosystemic destruction in their lending decision banks play an active role in the ecological transition.

|  |  |
| --- | --- |
|  | (5.38) |
|  | (5.39) |

#### Inside money creation

Inside money creation is the sum effective credit granted to social firms and listed firms (5.49). It is decomposed into a ‘green’ and a ‘brown’ component ((5.41) and (5.42)). The stock of inside money is the sum of its lagged value, plus the new flow (5.43).

|  |  |
| --- | --- |
|  | (5.40) |
|  | (5.41) |
|  | (5.42) |
|  | (5.43) |

### FINANCING (LIABILITIES)

#### Cash and deposit liabilities

Commercial banks fully accommodate households’ demand for cash and the demand for bank deposits from households and investment funds ((5.50) and (5.51)).

|  |  |
| --- | --- |
|  | (5.50) |
|  | (5.51) |

#### Refinancing operations

Banks’ mandatory holdings of Central Bank reserves are a fixed ratio of deposits ( (5.52).

|  |  |
| --- | --- |
|  | (5.52) |

The banking sector’s stock of Central Bank loans equals the required volume of reserves , net of reserves supplied by the Central Bank through quantitative easing (5.53).

|  |  |
| --- | --- |
|  | (5.53) |

The Central Bank accommodatively supplies reserve loans to the banking sector (Moore, 1988) (5.54).

|  |  |
| --- | --- |
|  | (5.54) |

Banks accommodate the Central Bank’s asset repurchase programs, so that the demand for reserve money ) issued through quantitative easing is equal to its supply (5.55).

|  |  |
| --- | --- |
|  | (5.55) |

Banks’ holdings of excess reserves parked at the deposit facility is the gap between total reserve holdings and the sum of mandatory reserves and circulating cash (equation (5.56))[[3]](#footnote-4).

|  |  |
| --- | --- |
|  | (5.56) |

#### Banks’ balance sheet

The banking sector’s equity, with or without Central Bank intervention and , respectively) is deducted from its balance sheet (5.58) and (5.59).

|  |  |
| --- | --- |
|  | (5.58) |
|  | (5.59) |

Since the 2008 financial crisis, Central Banks frequently intervene in secondary markets for financial stabilization purposes[[4]](#footnote-5). In this model, the Central Bank undertakes quantitative easing (QE) operation, when necessary, to align the capital adequacy ratio with its regulatory target. Whenever the banking sector’s capital risk-weighted ratio falls below its safe value (), the Central Bank extracts risky assets from banks’ balance sheets by creating new reserves deposits.

To calculate banks’ balance sheets, one thus needs to distinguish between banks’ *ex-ante* and *ex-post* asset portfolios ( and , respectively) (i.e. before and after any quantitative easing intervention).

The *ex-ante* portfolio () consists of mandatory reserve holdings (), Treasuries holdings valued at market price , the total stock of risky assets (also valued at market price) (5.60).

|  |  |
| --- | --- |
|  | (5.60) |

The ex-post portfolio () consists of mandatory reserve holdings (), reserve assets accumulated as a result of quantitative easing (), Treasuries valued at market price , and banks’ final holding of risky assets (valued at market price) (5.61).

|  |  |
| --- | --- |
|  | (5.61) |

Banks’ liabilities () feature reserves loans from the Central Bank and total deposits ) (5.62).

|  |  |
| --- | --- |
|  | (5.62) |

### REGULATION

#### Capital adequacy ratio (CAR)

Banks’ *ex-post* weighted risky asset portfolio is *ex-ante* weighted risky assets net of weighted repurchased assets and (5.70).

|  |  |
| --- | --- |
|  | (5.70) |

Given the *ex-ante* value of banks’ weighted risky assets , the Central Bank calibrates the size of its repurchased asset portfolio to keep the *ex-post* weighted risky assets ( below its upper bound, so that if .

Prudential supervisors compare the above with the *ex-ante* value of banks weighted risky assets . The latter is the product of the market value of the stocks of loans, bonds and commercial paper showing up in the asset side of the banking sector’s balance sheet and a risk parameter (5.71).

|  |  |
| --- | --- |
|  | (5.71) |

The Central Bank’s targeted stock of quantitative easing realigns the ex-post value of banks risky assets with the upper bound ((5.72) and (5.73)). This mechanism only kicks in scenarios where the variable is set to one. In scenarios when is set to zero, the Central Bank does not intervene.

|  |  |
| --- | --- |
|  | (5.72) |
|  | (5.73) |

From a prudential perspective, the upper bound for banks’ weighted risky asset holdings is given by the ratio between their *ex-ante* equity and the regulatory CAR target () (equation (5.74)).

|  |  |
| --- | --- |
|  | (5.74) |

We shall again distinguish the *ex-ante* from the *ex-post* capital adequacy ratio ( and , respectively) (i.e. before and after any quantitative easing) ((5.75) and (5.76)).

|  |  |
| --- | --- |
|  | (5.75) |
|  | (5.76) |

#### Liquidity ratio (LCR)

We use equation (5.79) to express banks targeted stock of Treasuries as the value which will align the *ex-post* liquidity coverage ratio with its regulatory target (5.77) (). The corresponding flow of Treasury purchases is given in (5.78). The *ex-post* liquidity coverage ratio is given in (5.81).

|  |  |
| --- | --- |
|  | (5.77) |
|  | (5.78) |

Banks continually adjust their Treasuries holdings to align the liquidity ratio with the regulatory target (). We shall thus differentiate the *ex-ante* from the *ex-post* liquidity ratio.

The ex-ante liquidity ratio equals the ratio of banks’ class 1 assets (including total reserve assets net of households’ cash holdings ) and Treasury bond holdings )) to total deposits factored by a parameter measuring banks’ assessment of households’ liquidity preference (5.78).

|  |  |
| --- | --- |
|  | (5.79) |

is an endogenous parameter which increases with (equation (5.79)). Therefore, the liquidity ratio target shall fall, for instance, in the event of a ‘bank run’ during which households’ preference for liquidity () increases. The latter is impacted by ecosystemic damages (see (2.53)).

|  |  |
| --- | --- |
|  | (5.80) |

The *ex-post* liquidity coverage ratio is given in (5.80).

|  |  |
| --- | --- |
|  | (5.81) |
|  | (5.82) |

## Investment funds (Module 6)

Investment funds profits are the sum of dividends paid by banks and listed firms , and interest earned on Treasuries and banking deposits ( (6.01). These profits are paid out in full to rentier households as fund dividends (6.02).

|  |  |
| --- | --- |
|  | (6.01) |
|  | (6.02) |

### INVESTMENT (ASSETS)

Investment funds use these ‘loanable funds’ portfolios to purchase equities. Funds thus hold the total stock of listed firms’ equities (6.10).

In cases where , investments funds turn to the Treasuries market where they act as second-order buyers (the priority in the adjudication of Treasuries being given to banks). Finally, any remaining funds are held as bank deposits.

|  |  |
| --- | --- |
|  | (6.10) |

Funds’ holdings of Treasuries equal its lagged value, plus annual transactions (6.11). The latter are equal to the gap between annual Treasuries issues and banking sector purchases (6.12). This implies that investment funds are second-order purchasers in Treasury issues.

|  |  |
| --- | --- |
|  | (6.11) |
|  | (6.12) |

Finally, banking deposits are inferred from the balance sheet constraint (6.13).

|  |  |
| --- | --- |
|  | (6.13) |
|  | (6.14) |

### FINANCING (LIABILITIES)

Investment funds raise capital by issuing shares in response to the demand of rentier households (6.20).

|  |  |
| --- | --- |
|  | (6.20) |

### Hidden equation

The equality between the flow of equity purchases by investment funds (as implied by their balance sheet) and new shares issues by listed companies shows up as our redundant equation:

|  |  |
| --- | --- |
|  |  |

This equation implies that equity market financing is limited by the availability of loanable funds represented by the appetite of rentier households for investment fund shares.

## The Central Bank (Module 7)

#### Income statement

The annual net income of the Central Bank equals the sum of the interest earned on its portfolio of repurchased assets and the interest earned through refinancing operations banks , net of the remuneration of mandatory reserves at the specified rate () and the remuneration of excess reserves at the deposit facility rate (7.01).

|  |  |
| --- | --- |
|  | (7.01) |

### INVESTMENT (ASSETS)

#### Quantitative easing operations

The next equations define the Central Bank’s annual transactions for each category of risky assets. Consider equation (7.12). It shows that the annual Central Bank demand for portfolios of brown loans issued to listed firms equals the new quantitative easing flow factored by the share of brown loans to listed firms in the debt market (equation (7.12)). A similar procedure is used to compute the value of repurchased green loans to listed firms , brown and green loans to social firms and ), brown and green corporate paper and , and brown and green corporate bonds and ((7.10) to (7.17)).

|  |  |
| --- | --- |
|  | (7.10) |
|  | (7.11) |
|  | (7.12) |
|  | (7.13) |
|  | (7.14) |
|  | (7.15) |
|  | (7.16) |
|  | (7.17) |

Quantitative easing interventions are ‘market neutral’ and do not affect the green structure of bank balance sheets whatsoever.

Equations (7.18) through (7.22) decompose the flow of asset repurchases into a brown and green component for listed firm loans , social firm loans (, bonds , and commercial paper .

|  |  |
| --- | --- |
|  | (7.18) |
|  | (7.19) |
|  | (7.20) |
|  | (7.21) |
|  | (7.22) |

The Central Bank’s demand for Treasuries ( is a residual buffer between annual Treasury issues , and net purchases of Treasuries by banks and investment funds . This means that the Central Bank can either sell Treasuries when the demand exceeds supply (in this case, reserves reflux on its balance sheet) or intervene as a buyer of last resort through outright monetary transactions (this implies the creation of new reserve deposits) ((7.23) and (7.24)).

|  |  |
| --- | --- |
|  | (7.23) |
|  | (7.24) |

Equations (7.25) to (7.35) are accounting equalities defining the green structure of the Central Bank’s repurchased asset portfolio. Consider for instance (7.25), it shows that the Central Bank’s portfolio of repurchased brown loans to listed corporations equals the stock inherited from the previous period , plus the new flow . Stocks of green loans to listed firms , brown and green loans to social firms ( and ) respectively), brown and green corporate paper ( and ) respectively), and brown and green corporate bonds ( and ) respectively) are determined with a similar procedure.

|  |  |
| --- | --- |
|  | (7.25) |
|  | (7.26) |
|  | (7.27) |
|  | (7.28) |
|  | (7.29) |
|  | (7.30) |
|  | (7.31) |
|  | (7.32) |
|  | (7.33) |
|  | (7.34) |
|  | (7.35) |

#### High powered money

The creation of high-powered money () is the sum of new reserve loans to banks (), flows of quantitative easing (), annual purchases of Treasuries , new cash issues in response to household demand () (7.36). The stock of high-powered money is equal to the stock inherited from the previous period, plus the annual flow (equation (7.37)).

|  |  |
| --- | --- |
|  | (7.36) |
|  | (7.37) |

### FINANCING (LIABILITIES)

#### Reserve liabilities

QE-created reserve deposits are the counterpart of the stock of repurchased assets (7.40).

|  |  |
| --- | --- |
|  | (7.40) |

New reserve deposits ) show up as Central Bank liabilities as the counterpart of Central Bank’s holdings of Treasuries (7.41).

|  |  |
| --- | --- |
|  | (7.41) |

The Central Bank’s liabilities () featured on its balance sheet have four components: those issued to the banking sector through refinancing operations , through quantitative easing , through the purchase of Treasuries (, and the supply of cash held by households (7.42).

|  |  |
| --- | --- |
|  | (7.42) |

#### Equity

The annual variation of the Central Bank’s equity equals the difference between changes in assets (reserves loans (), repurchased assets (), Treasuries holdings and liabilities (high powered money ) (equation (7.50)). The stock of Central Bank equity is equal to lagged value, plus the annual variation (equation (7.51)). Both Central Bank profits and equity are transferred to the Treasury, for accounting purposes (Nersisyan and Wray, 2024).

|  |  |
| --- | --- |
|  | (7.50) |
|  | (7.51) |

## Interest rates (Module 8)

#### 

#### Money market rates

The interest rate structure follows a post-Keynesian horizontalist framework (Moore, 1988). The supply of reserves is modeled as a set of horizontal lines, representing different stances of discretionary monetary policy. In addition, the transmission channel follows a pure floor framework[[5]](#footnote-6), in which the interbank rate follows that of the Central Bank deposit facility rate. By supplying of reserves more than the regulatory threshold, the Central Bank corners the interbank market by adjusting the deposit facility rate at the required level. The interbank market rate follows that of the deposit facility rate ((8.01) and (8.02)).

|  |  |
| --- | --- |
|  | (8.01) |
|  | (8.02) |

Monetary policy stances influence the credit market by affecting banks’ lending risk (see (5.36) and (5.37)) as well as lending rates ((8.05) and (8.06)). As in the Eurozone, the deposit facility rate differs from that paid on mandatory reserves requirement, with (8.03).

|  |  |
| --- | --- |
|  | (8.03) |

#### Bank lending rates

The determination of lending rates is based on the post-Keynesian principle of increasing risk. It also takes a ‘greenium’ mechanism into account.

The greenium is equal to a baseline parameter , modulated by climate destruction () (8.04).

|  |  |
| --- | --- |
|  | (8.04) |

Banks determine lending rates for highly liquid commercial paper given a chosen mark-up over the Central Bank rate. The mark-up reflects lender risk (see (5.36) and (5.37)), an exogenous liquidity premium and a *greenium* ((8.05) and (8.06)).

|  |  |
| --- | --- |
|  | (8.05) |
|  | (8.06) |

The interest rate on brown and green loans to listed firms equals the coupon rate of corporate paper, plus a liquidity risk premium ((8.07) and (8.08)).

|  |  |
| --- | --- |
|  | (8.07) |
|  | (8.08) |

The coupon rate for brown and green corporate bonds equals to the interest rate on loans ( and , respectively), (equation (8.09) and (8.10)).

|  |  |
| --- | --- |
|  | (8.09) |
|  | (8.10) |

The interest rate on brown and green loans to social firm equates that charged to listed corporations, plus a lander-specific risk premium ((8.11) and (8.12)).

|  |  |
| --- | --- |
|  | (8.11) |
|  | (8.12) |

#### Deposit rates

Banks determine the deposit rate by applying a mark-up (to the refinancing rate (8.13).

|  |  |
| --- | --- |
|  | (8.13) |

#### Treasuries rate

The interest rate on government bonds is equal to the interbank rate , plus a short-term liquidity risk premium (8.14).

|  |  |
| --- | --- |
|  | (8.14) |

Given the above framework, the shape of the yield curve follows a standard term structure so that: . In addition, the risk structure of interest takes a different shape for brown and green project due to the *greenium* mechanism.

## Financial markets (Module 8)

#### Total returns

The total annual return on corporate bonds, Treasuries and securitized loan portfolios is the sum of the coupon rate and the realized capital gain. Consider for instance (8.20). It shows that the total return on brown corporate bonds is the sum of the corresponding yield rate and the percent capital gain . This procedure also applies to green corporate bonds , brown and green loans to listed firms ( and , respectively), and brown and green loans to social firms ( and , respectively), and Treasuries ((8.20) to (8.26)). The return on investment shares is equal to the dividend yield (8.27).

|  |  |
| --- | --- |
|  | (8.20) |
|  | (8.21) |
|  | (8.22) |
|  | (8.23) |
|  | (8.24) |
|  | (8.25) |
|  | (8.26) |
|  | (8.27) |

#### Realized capital gains

Realized capital gains equal to the first-differenced market prices, factored by lagged outstanding asset volumes. For instance, capital gains on Treasuries are the product of price changes and the lagged outstanding stock of Treasuries (8.33). A similar logic is applied to brown and green corporate bonds () and ), respectively), portfolios of brown and green loans to listed corporations () and ), respectively), portfolios of brown and green loans to third sector firms () and ), respectively), and equities ((8.28) to (8.34)).

|  |  |
| --- | --- |
|  | (8.28) |
|  | (8.29) |
|  | (8.30) |
|  | (8.31) |
|  | (8.32) |
|  | (8.33) |
|  | (8.34) |
|  | (8.35) |

Under the steady state scenario, all market prices are stationary, i.e. (*i* representing the range of available assets). However, specific shocks can be introduced on market prices in different segments of financial markets.

#### Expected capital gains

Expectations are modelled with adaptive expectations. Expected capital gains equal their lagged value, plus an error correction term, where represents the speed of expectations adjustment. For instance, the expected capital gain on brown bonds is equal to its lagged value , plus a factor ) of the last observed expectation error . A similar process describes expectations for green bonds , brown and green loans to listed firms ( and , respectively) , brown and green loans to social firms ( and , respectively), Treasuries ) and equities ((8.35) to (8.42)).

|  |  |
| --- | --- |
|  | (8.36) |
|  | (8.37) |
|  | (8.38) |
|  | (8.39) |
|  | (8.40) |
|  | (8.41) |
|  | (8.42) |
|  | (8.43) |

## The public sector (Module 9)

#### Public budget balance

Basically, the public budget balance is positive depending on whether taxes exceed expenditure and interest on bond debt . Central bank income contributes positively to the public budget balance (equation (9.01)).

|  |  |
| --- | --- |
|  | (9.01) |

#### Public sector firms

Public sector firms’ profit is the sum of sales revenues and investment ), net of the wage bill and depreciation expenses (equation (9.02)).

|  |  |
| --- | --- |
|  | (9.02) |
|  | (9.03) |
|  | (9.04) |

### INVESTMENT (ASSETS)

#### The government’s budget constraint

Government spending has two components. The first is set exogenously and takes the form of subsidies to social firms ( and listed firms ((9.10) and (9.12)). The second component responds to the net investment financing needs of state-owned firms (9.13).

|  |  |
| --- | --- |
|  | (9.10) |
|  | (9.11) |
|  | (9.12) |
|  | (9.13) |

Government spending includes direct spending in the private sector ), investment expenses of public-sector firms , and interest payment to Treasuries holders ). Government revenue includes total taxes ), state-owned firms’ distributed profits ) and central bank profit and equity revaluation ). The latter item is included here for the purpose of accounting consistency (Nersisyan and Wray, 2024).

In contrast to private sector firms, investment demand in the public sector is an exogenous policy variable. Public sector firms’ productive capital target equals the lagged capital stock ) factored by a discretionary growth ratePublic sector firms’ demand for investment ) is the difference between capital target and the lagged stock ), plus depreciation expenditure ((9.14) to (9.16)). The depreciation and amortization expenditures () of public sector firms are a fixed proportion of the lagged capital stock () (9.17).

|  |  |
| --- | --- |
|  | (9.14) |
|  | (9.15) |
|  | (9.16) |
|  | (9.17) |

The green structure of public sector investment demand is also a policy variable. The effective demand for green capital goods is an exogenous fraction of the total demand for capital goods ). The demand for brown capital goods is determined through accounting closure (9.19). Public sector investment is unrestricted as supply ) equals demand (equation (9.20)).

|  |  |
| --- | --- |
|  | (9.18) |
|  | (9.19) |
|  | (9.20) |

### FINANCING (LIABILITIES)

#### Tax payments

Taxes ) are paid by working households’ , rentier households , social firms ( and listed firms ((9.30) to (9.34))[[6]](#footnote-7).

|  |  |
| --- | --- |
| + | (9.30) |
|  | (9.31) |
|  | (9.32) |
|  | (9.33) |
|  | (9.34) |

#### Treasury issues

Fresh Treasury issues fill in the gap between spending and revenue (9.35). The volume of outstanding public debt equals the lagged volume of Treasuries plus new issues (9.36).

|  |  |
| --- | --- |
|  | (9.35) |
|  | (9.36) |

## The eco-systemic block (Module 10)

#### Material extraction

The socio-economic stock is the sum of material production and the lagged socio-economic stock , net of the discarded stock ) (10.01).

|  |  |
| --- | --- |
|  | (10.01) |

The discarded socio-economic stock (10.), depends on a share ) of the sum of the lagged socio-economic stock and the total obsolescence of capital goods (10.02).

|  |  |
| --- | --- |
|  | (10.02) |

The production of material goods is a proportion of annual real GDP (10.03). This proportion is modulated by the productive structure of the economy, i.e. the share of green and brown capital (10.04).

|  |  |
| --- | --- |
|  | (10.03) |
|  | (10.04) |

Annual material extraction ( is the difference between material production and the recycled socio-economic stock (10.05). The latter is a proportion of the discarded socio-economic stock (10.06).

|  |  |
| --- | --- |
|  | (10.05) |
|  | (10.06) |

Material waste emissions are the difference between the discarded stock ) and recycling (10.07).

|  |  |
| --- | --- |
|  | (10.07) |

Material reserves ( are equal to their lagged value net of the conversion of resources into reserves and material extraction ( (10.08). The conversion of natural reserves into material stocks is a fraction of lagged material resources (10.09). Material resources equal their lagged value net of the new conversions into reserves (10.10).

|  |  |
| --- | --- |
|  | (10.08) |
|  | (10.09) |
|  | (10.10) |

#### Energy consumption

Changes in the stock of non-renewable energy reserves ( equal the conversion of energy resources into reserves net of non-renewable energy consumption (10.20). The conversion of energy reserves into resources occurs at rate

|  |  |
| --- | --- |
|  | (10.20) |
|  | (10.21) |

Total energy consumption is broken down into renewable energy and non-renewable energy , based on a green energy mix parameter ((10.22) and (10.23)). Total energy consumption is indexed on real GDP, with the conversion rate depending on the state of eco-efficiency technological capacities () and the green energy mix (10.24). We assume a delayed diffusion of green technologies in the economy. As shown in equation (10.25), the green technological efficiency is equal to its lagged value, plus a simple moving average of past greening of productive capital over k periods.

|  |  |
| --- | --- |
|  | (10.22) |
|  | (10.23) |
|  | (10.24) |
|  | (10.25) |

Total energy consumption dissipates as heat () according to the second law of thermodynamics (10.26).

|  |  |
| --- | --- |
|  | (10.26) |

#### Emissions

Total CO2 emissions are the sum of land emissions (emissions declining at a rate ()) and industrial emissions which are indexed on the consumption of non-renewable energy with an endogenous parameter measuring the carbon intensity of non-renewable energy (equations (10.30) to (10.32)).

|  |  |
| --- | --- |
|  | (10.30) |
|  | (10.31) |
|  | (10.32) |

Oxygen inputs are equal to the difference between total CO2 emissions and the carbon mass (10.33). The carbon mass is a fixed ratio of CO2 emissions (10.34).

|  |  |
| --- | --- |
|  | (10.33) |
|  | (10.34) |

#### The carbon cycle

The accumulation of CO2 in the atmosphere increases radiative forcing and, eventually, both atmospheric and oceanic temperatures and ((10.35) to (10.38)).

|  |  |
| --- | --- |
|  | (10.35) |
|  | (10.36) |
|  | (10.37) |
|  | (10.38) |

Equations (10.39) to (10.41) describe a simplified carbon cycle: the net transfers of carbon from the atmosphere to the biosphere and ocean reservoirs and increase the atmospheric concentration of CO2 .

|  |  |
| --- | --- |
|  | (10.39) |
|  | (10.40) |
|  | (10.41) |

#### Eco-efficiency

The level of eco-efficiency depends both on the green taxonomy of productive capital and on technology affecting total energy consumption.

The carbon intensity of non-renewable energy, the energy intensity of GDP , and the share of renewable energy in the energy mix are defined as the weighted sum of the share of brown capital and green capital in the total capital stock (and , respectively) (equations (10.50) to (10.52)).

|  |  |
| --- | --- |
|  | (10.50) |
|  | (10.51) |
|  | (10.52) |

Endogenous technological change ) affects energy consumption and carbon emissions. With the diffusion of greener technologies, the energy intensity of GDP and the carbon intensity of non-renewable energy both decline (equations (10.53) and (10.54), respectively), while the share of renewables in the energy mix increases (equation (10.55)).

|  |  |
| --- | --- |
|  | (10.53) |
|  | (10.54) |
|  | (10.55) |

#### Ecosystemic retroaction

The depletion ratios of material and energy reserves are obtained by dividing material extraction and non-renewable energy consumption by lagged material and energy reserves ((10.56) and (10.57), respectively). Climate-induced economic damage is a nonlinear function of changes in atmospheric temperature (10.58).

|  |  |
| --- | --- |
|  | (10.56) |
|  | (10.57) |
|  | (10.58) |

## Biomimicry-inspired postgrowth metrics (Module 11)

#### Monetary trophic flows

Following Ulanowicz et al. (2009), let be the trophic monetary outflow of each sector to any other sector; the trophic monetary inflow of sector from any other sector; and money outflow of any sector to any sector . The sum of all net money transfers of money between sector and is . Table A4 contains these intersectoral monetary ‘trophic’ flows, which are discussed in the following equations.

Equation (11.01) defines the money transfer of working household to social firms as consumption spending . Equation (11.02) defines the money transfer of working households to listed firms with an accounting criterion. Equations (11.03) and (11.04) apply similar principles to define money transfer of rentier household to social firms , and listed firms . Equation (11.05) defines the money transfer of rentier households to investment funds as new share purchases ). Equation (11.06) and (11.07) define total money transfer of working households and rentier households to the private sector.

|  |  |
| --- | --- |
|  | (11.01) |
|  | (11.02) |
|  | (11.03) |
|  | (11.04) |
|  | (11.05) |
|  | (11.06) |
|  | (11.07) |

Equation (11.10) defines the money transfer of social firms to working households as the sum of the wage bill ) and distributed surpluses . Equation (11.11) defines the money transfer of social firms to the banking sector as the sum of interest payments on green and brown loans . Equation (11.12) defines the total money transfer of social firms to the rest of the private sector .

|  |  |
| --- | --- |
|  | (11.10) |
|  | (11.11) |
|  | (11.12) |

Equation (11.20) defines the money transfer of listed firms to working households as the wage bill ). Equation (11.21) defines the money transfer of listed firms to the banking sector as the sum of interest payments on green and brown loans , green and brown bonds and green and brown commercial paper . Equation (11.22) defines the money transfer of listed firms to investment funds as paid out dividends . Equation (11.23) defines the total money transfer of social firms to the rest of the private sector .

|  |  |
| --- | --- |
|  | (11.20) |
|  | (11.21) |
|  | (11.22) |
|  | (11.23) |

Equation (11.30) defines the money transfer of banks to working households as interest on deposits ). Equation (11.31) defines the money transfer of banks to rentier households as interest on deposits . Equation (11.32) defines the money transfer of banks to the social firm sector as annual credit flows . Equation (11.33) defines the money transfer of banks to the social firm sector as annual credit flows . Equation (11.34) defines the money transfer of banks to investment funds as annual dividend payments . Equation (11.35) defines the total money transfer of banks to the private sector .

|  |  |
| --- | --- |
|  | (11.30) |
|  | (11.31) |
|  | (11.32) |
|  | (11.33) |
|  | (11.34) |
|  | (11.35) |

Equation (11.40) defines the money transfer of investment funds to rentier households as distributed profits ). Equation (11.41) defines the money transfer of investment funds to listed firms as new equity purchases ). Equation (11.42) gives the total money transfer of investment funds to the private sector .

|  |  |
| --- | --- |
|  | (11.40) |
|  | (11.41) |
|  | (11.42) |

Equations (11.50) to (11.56) are macro aggregates corresponding the last row and columns of table A4. They measure total money flows to the working household sector , the rentier household sector , the social firm sector , the listed firm sector , the banking sector , investment funds and the total money transfers , respectively.

|  |  |
| --- | --- |
|  | (11.50) |
|  | (11.51) |
|  | (11.52) |
|  | (11.53) |
|  | (11.54) |
|  | (11.55) |
|  | (11.56) |

**Table A4 Money trophic flows**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| i j | Working households | Rentier households | Social firms | Listed corporations | Banks | Investment funds | All |
| Working households |  |  |  |  |  |  |  |
| Rentier households |  |  |  |  |  |  |  |
| Social firms |  |  |  |  |  |  |  |
| Listed corporations |  |  |  |  |  |  |  |
| Banks |  |  |  |  |  |  |  |
| Investment funds |  |  |  |  |  |  |  |
| All |  |  |  |  |  |  |  |

Note: this table shows private sector trophic flows within Philia 1.0. The first column lists the originating sector, and the first line lists the receiving sector.

#### Boltzmann transformation

Defining the sum of all net transfers of money between units and as , the realization probability of each transaction is given by its frequency:

;

Following Ulanowicz et al. (2009), the ‘evolutionary capacity’ of the private sector is then equal to , which states that a system's capacity for evolutionary change or self-organization depends on a complementary balance between ascendency ) —its ability to maintain integrity through directed power—and flexibility reserve ) —its reserve of adaptive actions to respond to novel disturbances, where each term is defined in equations (11.60) to (11.62):

|  |  |
| --- | --- |
|  | (11.60) |
|  | (11.61) |
|  | (11.62) |

Defining yields the economy’s fitness for evolution ) through a Boltzmann transformation (equation (11.62)).

|  |  |
| --- | --- |
|  | (11.63) |

Where *k* is a positive scalar set to 2.71. If 1, tends to zero, because the ability to adapt to shocks is insufficient. If 0, then also tends to zero because the system is insufficiently structured. takes significant values for intermediate values of and reaches its maximum at = 0.36. (figure A3).

**Figure A3 Fitness for evolution and resilience**



Note: this graph represents the ability of the system to evolve for different values of 0< a <1. The dotted line indicates values above 0.954 and the resilience window. See Ulanowicz et al (2009) for more details.

## Accounting closure

The model’s accounting closure can be assessed by comparing each item on table A1, A2 and A3 with its predicted accounting counterpart which we calculate from the opposite line or column. For example, taking line 10 of Table 1, we verify that . The 48 accounting closure tests are shown in figure A3 to A11.

**Figure A3: Accounting closure, income and spending**



**Figure A4: Accounting closure, income and spending (cont’d)**



**Figure A5: Accounting closure, income and spending (cont’d)**



**Figure A6: Accounting closure, assets and liabilities**



**Figure A7: Accounting closure, assets and liabilities (cont’d)**



**Figure A8: Accounting closure, sectoral budget constraints**



**Figure A9: Accounting closure, sectoral budget constraints**



**Figure A10: Material and energy closure**



**Figure A11: Physical stocks and flows closure**



## Economic block: steady state criteria

Policy analysis in Philia 1.0 is made in reference to a theoretical steady state where all variables reach credible values and grow at a constant rate. This condition, as highlighted in Godley and Lavoie (2012, p. 71) applies to “*both flows and stocks, and not flows only as with short-run (temporary) equilibria*” .The conditions for two variables i and j to grow at the same rate = can be derived as follows:

If = then . At the steady state, holds for key flow/flow, flow/stock and stock/stock ratios. The model’s aggregate key flow variables include GDP, consumption, the wage bill, and total disposable income (which includes wages as well as distributed profits, surpluses and other rents, net of taxes). The aggregate key stock variables include the productive capital stock and total household financial wealth.

As mentioned in Godley and Lavoie (2012) a consistent model should reach a steady state on its own after a transient period. Figures A3 to A5 show the corresponding flow/flow, flow/stock and stock/stock ratios under the steady state (which is reached after 150 iterations using the Eviews’ Broyden algorithm).

*.*

**Fig R6 Flow/flow ratios**



Note: the ratios shown in this figure are taken in first difference.

**Fig R7 Flow/stock and stock/stock ratios**



Note: the ratios shown in this figure are taken in first difference.

**Fig R8 Flow/stock and stock/stock ratios**



Note: the ratios shown in this figure are taken in first difference.

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1. See Godley and Lavoie (2012, p. 293) for a definition of inflation-accounted household real disposable income. [↑](#footnote-ref-2)
2. While we use the term effective loan ‘supply’ to simplify notations, the flow of loans issued by the banking sector is always demand-driven: “*There is a notional demand curve, which corresponds to the demand for loans by entrepreneurs, according to their expectations. Then there is another demand curve, the ‘effective’ demand curve, which takes into account only the demand that responds to the conditions and expectations of the bankers*” (Lavoie, 2022, p. 248) [↑](#footnote-ref-3)
3. Each individual bank may of course exchange these excess reserves for interest-bearing financial instruments. In this case, excess reserves are transferred from one bank's balance sheet to another, leaving the consolidated balance sheet of the banking sector, as well as the amount showing up as a liability on the central bank's balance sheet, unchanged. [↑](#footnote-ref-4)
4. In the case of the euro area: "*monetary policy cannot turn a blind eye to rising financial stability risks. This was one of the main conclusions of our monetary policy strategy review, which we completed in July of this* year" (Isabel Schnabel, executive board of the ECB, December 2021). See <https://www.ecb.europa.eu/press/key/date/2021/html/ecb.sp211208_2~97c82f5cfb.en.html> [↑](#footnote-ref-5)
5. Variants of the floor system have become the new paradigm in Central Banking since the 2008 crisis. See Schnabel (2024). The Eurosystem’s operational framework. Speech by Isabel Schnabel, member of the Executive Board of the ECB. <https://www.ecb.europa.eu/press/key/date/2024/html/ecb.sp240314~8b609de772.en.html> [↑](#footnote-ref-6)
6. To understand equations (9.33) and (9.34), note that, letting S represent before-tax profit, P the after-tax profit, T tax payments, the dividend payout ratio and *θ* the tax rate, then . Given that , then . Equation (9.33) is a specific case where . [↑](#footnote-ref-7)