DEFINE - HOUSING: Manual

Version 2.0

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The DEFINE-HOUSING 2.0 model extends DEFINE-HOUSING 1.0 by incorporating green securitisation and shadow banking sectors into the structure of the financial system. This permits the combined analysis of green housing and green securitisation dynamics and the study of the macro-financial and environmental effects of a wider range of green financial policies. The economy of DEFINE-HOUSING 2.0 consists of nine sectors: worker households, investor (rentier) households, firms, commercial banks, Finance Vehicle Corporations (FVCs), Investment Funds (IFs), Money Market Funds (MMFs), the government sector and the central bank.

Worker households take out green/conventional mortgages from commercial banks. Commercial banks provide loans to worker households and firms. These loans can be either green or conventional ones. Only a proportion of the mortgages that are demanded by worker households are provided (i.e. there is credit rationing). Commercial banks securitise part of their green mortgages and sell them to FVCs. The FVCs transform these green mortgages into green Mortgage Backed Securities (MBSs). The green MBSs are bought by IFs (they issue repos to finance their purchases) and MMFs (they issue shares that are bought by investor households).

The balance sheet and the transactions flow matrices are shown in Table A.1 and Table A.2, respectively. The balance sheet matrix highlights the assets and liabilities of the economy, while the transactions flow matrix captures the flows and changes in assets and liabilities across sectors. The balance sheet matrix and the transactions flow matrix have been used to identify the identities of the model from each column and each row with more than two entries. Moreover, there are two equations that are derived by using the transactions flow matrix that refer to the same variable. Only one of them can be used in the simulations. The other one is used to make sure that the model is consistent. The equation linked to this is the redundant equation.[1] Government securities bought by the central bank are the variable that we use to check the consistency of the model.

[1]This equation in SFC models is implied by the accounting identities and is therefore redundant (see e.g. Godley and Lavoie 2012).

Table A.1: Balance sheet matrix

	Worker households	Investor (rentier) households	Firms	Commercial banks	Financial Vehicle Corporations (FVCs)	Investment Funds (IFs)	Money Market Funds (MMFs)	Government sector	Central bank	Total
Green houses	$+p_{Ht}H_{WOwnGt}$	$+p_{Ht}H_{IOwnGt}$ $+p_{Ht}H_{IRentGt}$ $+p_{Ht}H_{VacantGt}$ $-p_{Ht}H_{ConstrVacantGt}$	$+p_{Ht}H_{ConstrVacantGt}$							$+p_{Ht}H_{TotalGt}$
Conv. houses	$+p_{Ht}H_{WOwnCt}$	$+p_{Ht}H_{IOwnCt}$ $+p_{Ht}H_{IRentCt}$ $+p_{Ht}H_{VacantCt}$ $-p_{Ht}H_{ConstrVacantCt}$	$+p_{Ht}H_{ConstrVacantCt}$							$+p_{Ht}H_{TotalCt}$
Green housing loans	$-L_{HGt}$			$+L_{NSHGt}$	$+L_{SHGt}$					0
Conv. housing loans	$-L_{HCt}$			$+L_{HCt}$						0
Conv. capital			$+K_{Ct}$							$+K_{Ct}$
Green capital			$+K_{Gt}$							$+K_{Gt}$
Deposits	$+D_{HWt}$	$+D_{HIt}$		$-D_t$						0
Conv. loans			$-L_{Ct}$	$+L_{Ct}$						0
Green loans			$-L_{Gt}$	$+L_{Gt}$						0
Green MBSs					$-\bar{p}_{Mt}m_t$	$+\bar{p}_{Mt}m_{IFt}$	$+\bar{p}_{Mt}m_{MMFt}$			0
Green repos				$+Repo_t$		$-Repo_t$				0
Money markets' shares		$+SH_{MMFt}$					$-SH_{MMFt}$			0
Gov. securities		$+SEC_{HIt}$		$+SEC_{Bt}$	$+SEC_{FVCt}$	$+SEC_{IFt}$	$+SEC_{MMFt}$	$-SEC_t$	$+SEC_{CBt}$	0
High-powered money				$+HPM_t$					$-HPM_t$	0
Advances				$-A_t$					$+A_t$	0
Total (net worth)	$+V_{HWt}$	$+V_{HIt}$	$+V_{Ft}$	$+CAP_t$	$+K_{FVCt}$	$+K_{IFt}$	$+K_{MMFt}$	$-SEC_t$	$+V_{CBt}$	$+K_{Gt} + K_{Ct}$ $+p_{Ht}H_{Totalt}$

Table A.2: Transactions flow matrix

	Worker households	Investor (rentier) households	Firms		Commercial banks		Financial vehicle corporations (FVCs)		Investment funds (IFs)		Money Market Funds (MMFs)		Government sector		Central bank		Total
			Current	Capital	Current	Capital	Current	Capital	Current	Capital	Current	Capital	Current	Capital	Current	Capital	
Green housing investment			$+I_{ConstrGt}$	$-I_{ConstrGt}$													0
Conv. housing investment			$+I_{ConstrCt}$	$-I_{ConstrCt}$													0
Investment in refurbishment		$-I_{Refurbt}$	$+I_{Refurbt}$														0
Private consumption	$-CO_{HWt}$	$-CO_{HIt}$	$+CO_{HWt}$ $+CO_{HIt}$														0
Government net savings													$-GNS_t$	$+GNS_t$			0
Government consumption			$+CO_{GOVt}$										$-CO_{GOVt}$				0
Green investment			$+I_{Gt}$	$-I_{Gt}$													0
Conv. investment			$+I_{Ct}$	$-I_{Ct}$													0
Rents	$-Rent_t$	$+Rent_t$															0
Green new houses	$-p_{Ht}H_{WNewOwnOccupGt}$	$-p_{Ht}H_{INewOwnOccupGt}$ $-p_{Ht}H_{INewRentedGt}$		$+p_{Ht}H_{WNewOwnOccupGt}$ $+p_{Ht}H_{INewOwnOccupGt}$ $+p_{Ht}H_{INewRentedGt}$													0
Conv. new houses	$-p_{Ht}H_{WNewOwnOccupCt}$	$-p_{Ht}H_{INewOwnOccupCt}$ $-p_{Ht}H_{INewRentedCt}$		$+p_{Ht}H_{WNewOwnOccupCt}$ $+p_{Ht}H_{INewOwnOccupCt}$ $+p_{Ht}H_{INewRentedCt}$													0
Green interest subsidies	$+int_{SUB}L_{HGt-1}$													$-int_{SUB}L_{HGt-1}$			0
Taxes	$-TAX_{HWt}$	$-TAX_{HIt}$	$-TAX_{Ft}-TAX_{Ct}$										$+TAX_t$				0
Wages	$+W_t$		$-W_t$														0
Firms profit		$-DP_t$	$-TP_t$	$+RP_t$													0
Interest on green housing loans	$-int_{LHGt-1}L_{HGt-1}$				$+int_{LHGt-1}L_{NHGt-1}$		$+int_{LHGt-1}L_{SHGt-1}$										0
Interest on conv. housing loans	$-int_{LHCt-1}L_{HCt-1}$				$+int_{LHCt-1}L_{HCt-1}$												0
FVCs profits					$+FVCP_{Dt}$		$-FVCP_t$	$+FVCP_{Ut}$									0
Fees					$+FEE_t$		$-FEE_t$										0
IFs profits		$+IFP_{Dt}$							$-IFP_t$	$+IFP_{Ut}$							0
MMFs profits		$+MMFP_{Dt}$									$-MMFP_t$	$+MMFP_{Ut}$					0
Coupon payments							$-coupon_{t-1}m_{t-1}$		$+coupon_{t-1}m_{IFt-1}$		$+coupon_{t-1}m_{MMFt-1}$						0
Banks' profits		$+BP_{Dt}$			$-BP_t$	$+BP_{Ut}$											0
Interest on deposits	$+int_D D_{HWt-1}$	$+int_D D_{HIt-1}$			$-int_D D_{t-1}$												0
Interest on green loans			$-int_G L_{Gt-1}$		$+int_{Gt}L_{Gt-1}$												0
Interests on conv. loans			$-int_C L_{Ct-1}$		$+int_{Ct}L_{Ct-1}$												0
Interests on gov. securities		$+int_S SEC_{HIt-1}$			$+int_S SEC_{Bt-1}$		$+int_S SEC_{FVCt-1}$		$+int_S SEC_{IFt-1}$		$+int_S SEC_{MMFt-1}$		$-int_S SEC_{t-1}$		$+int_S SEC_{CBt-1}$		0
Interests on advances					$-int_{At-1}A_{t-1}$										$+int_{At-1}A_{t-1}$		0
Interest on green repos					$+int_R Repo_{t-1}$				$-int_R Repo_{t-1}$								0
Central bank's profits													$+CBP_t$		$-CBP_t$		0
ΔDeposits	$-\Delta D_{HWt}$	$-\Delta D_{HIt}$				$+\Delta D_t$											0
ΔGreen repos						$-\Delta Repo_t$				$+\Delta Repo_t$							0
ΔGreen MBSs								$+\bar{p}_M\Delta m_t$		$-\bar{p}_M\Delta m_{IFt}$		$-\bar{p}_M\Delta m_{MMFt}$					0
ΔGreen housing loans	$+\Delta L_{HGt}$					$-\Delta L_{NHGt}$		$-\Delta L_{SHGt}$									0
ΔConv. housing loans	$+\Delta L_{HCt}$					$-\Delta L_{HCt}$											0
ΔGreen firm loans				$+\Delta L_{Gt}$		$-\Delta L_{Gt}$											0
ΔConv. firm loans				$+\Delta L_{Ct}$		$-\Delta L_{Ct}$											0
ΔGov. securities		$-\Delta SEC_{HIt}$				$-\Delta SEC_{Bt}$		$-\Delta SEC_{FVCt}$		$-\Delta SEC_{IFt}$		$-\Delta SEC_{MMFt}$		$+\Delta SEC_t$		$-\Delta SEC_{CBt}$	0
ΔAdvances						$+\Delta A_t$										$-\Delta A_t$	0
ΔHigh-powered money						$-\Delta HPM_t$										$+\Delta HPM_t$	0
ΔMMF shares		$-\Delta SH_{MMFt}$										$+\Delta SH_{MMFt}$					0
Defaulted loans	$+DL_{HWt}$					$-DL_{NHt}$		$-DL_{FVCt}$									0
Total	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

We construct a housing stock-flow matrix. Table A.3 shows the stock-flow interactions which take place between own occupied houses by workers (first column), owned occupied houses by rentiers (fourth column), vacant houses (third column) and houses owned by rentiers and rented to workers (second column). The last column in Table A.3 shows the total number of houses. The first horizontal line in the Table shows the opening stock of houses. These are the houses that already exist. However, these opening stocks of houses might change because workers want to buy new houses or because rentiers would like to sell some of the houses that they own or rent, amongst other reasons. The last horizontal line in Table A.3 shows the closing stock of houses. Similarly, to the balance sheet matrix and transactions flow matrix, the housing stock-flow matrix is used to formulate the identities from each column and each row with more than two entries.

There is also a redundant equation in the housing market that needs to be considered in order for the values in the housing market to be consistent. The last column can be used to identify the number of total houses (H_{Totalt}) that increases by the new houses built by the firms (H_{FNewt}) (Eq. A.105). There is also a horizontal constraint that can be used to identify the total number of houses (Eq. A.104). According to this constraint, the total houses is equal to the houses owned by workers, the houses owned by the rentiers, the houses that are rented by worker households and owned by the rentiers and vacant houses. Both Eqs. (A.104) and (A.105) need to hold. So, we name one of them the redundant equation in the housing market.

The rest of this section presents a description of the equations of the model.

Table A.3: Housing stock-flow matrix

	Houses owned and occupied by workers	Houses owned by rentiers and rented to workers	Vacant houses for sale or rent	Houses owned and occupied by rentiers	Total houses
Opening stock	$H_{WOwnt-1}$	$H_{IRentt-1}$	$H_{Vacantt-1}$	$H_{IOwnt-1}$	$H_{Totalt-1}$
New houses	$+H_{WNewOwnOccupt}$	$+H_{INewRentedt}$	$+H_{ConstrVacantt}$	$+H_{INewOwnOccupt}$	$+H_{Constr}$
Existing houses converted from rented to sold	$+H_{IRentedSoldt}$	$-H_{IRentedSoldt}$			0
Existing houses converted from owned-occupied to rented		$+H_{IOwnOccupRentedt}$		$-H_{IOwnOccupRentedt}$	0
Existing houses converted from owned-occupied to sold	$+H_{WOwnOccupt}$			$-H_{WOwnOccupt}$	0
Vacant houses that have not been rented to workers			$+H_{IRentedVacantt}$	$-H_{IRentedVacantt}$	0
Vacant houses that are rented but have not been sold		$-H_{IRentedSoldVacantt}$	$+H_{IRentedSoldVacantt}$		0
Vacant houses that have not been sold to workers			$+H_{WOwnOccupVacantt}$	$-H_{WOwnOccupVacantt}$	0
Closing stock	H_{WOwnt}	H_{IRentt}	$H_{Vacantt}$	H_{IOwnt}	H_{Totalt}

Note: The table refers to million houses.

1.2. Worker households

Eq. (A.1) defines the gross disposable income of worker households (Y_{HWGt}), which is equal to wages, plus interest on deposits minus interest payments on green and conventional housing loans and rent ($Rent_t$), plus green interest subsidies; W_t is the wage income and int_D is the interest rate on deposits.[2] Eq. (A.2) shows the net disposable income (Y_{HWt}) which is the gross disposable income minus taxes that worker households pay (TAX_{HWt}). Eq. (A.3) describes the consumption of worker households (CO_{HWt}) which is a function of net disposable income and household wealth (V_{HWt}).[3] The above-mentioned equations show that the higher the interest subsidy on green loans, the higher the net disposable income and the higher the consumption of worker households; c_{11} and c_{12} show the propensities to consume out of net disposable income and wealth of worker households, respectively.

$$Y_{HWGt} = W_t + int_D D_{HWt-1} - int_{LHCt-1} L_{HCt-1} - int_{LHGt-1} L_{HGt-1} - Rent_t + int_{SUB} L_{HGt-1} \tag{A.1}$$

$$Y_{HWt} = Y_{HWGt} - TAX_{HWt} \tag{A.2}$$

$$CO_{HWt} = c_{11} Y_{HWt-1} + c_{12} V_{HWt-1} \tag{A.3}$$

Eq. (A.4) shows that worker households keep deposits as a proportion of their income. Worker households' wealth, as shown in Eq. (A.5), is the value of green and conventional houses owned by workers plus deposits of worker households minus the stock of both green and conventional loans.

Eqs. (A.6) and (A.7) define the desired amount of new green and conventional loans, respectively. For green loans, the desired new credit ($NLHG_{Dt}$) covers the demand for owned occupied houses plus the repayment of loans minus a proportion of the existing savings of the households; p_{Ht} is the housing price, rep_L is the repayment ratio, CO_{HWt} is the consumption of worker households and D_{HWt} are the deposits. The desired new conventional loans ($NLHC_{Dt}$) are defined in a similar way as the desired new amount of green loans.

Eq. (A.8) shows that the change in green housing loans is equal to the amount of new loans provided by commercial banks after credit rationing, repayment and default are considered; CR_{HGt} is the proportion of green loans that are credit rationed; def_{HWt} is the default rate on housing loans.[4] Similarly to Eq. (A.8), Eq. (A.9) shows the amount of conventional housing loans. The housing loans (L_{Ht}) is the sum of green and conventional housing loans, as shown in Eq. (A.10).

$$D_{HWt} = prop_D Y_{HWt-1} \tag{A.4}$$

$$V_{HWt} = p_{Ht} H_{WOwnGt} + p_{Ht} H_{WOwnCt} + D_{HWt} - L_{HGt} - L_{HCt} \tag{A.5}$$

$$\begin{aligned} NLHG_{Dt} = {} & (H_{DWOwnGt} - H_{WOwnGt-1}) p_{Ht-1} + rep_L L_{HGt-1} \\ & - \beta_{Ht}(Y_{HWt} - CO_{HWt} - (D_{HWt} - D_{HWt-1})) \end{aligned} \tag{A.6}$$

$$\begin{aligned} NLHC_{Dt} = {} & (H_{DWOwnCt} - H_{WOwnCt-1}) p_{Ht-1} + rep_L L_{HCt-1} \\ & - (1 - \beta_{Ht})(Y_{HWt} - CO_{HWt} - (D_{HWt} - D_{HWt-1})) \end{aligned} \tag{A.7}$$

$$L_{HGt} = L_{HGt-1} + (1 - CR_{HGt}) NLHG_{Dt} - rep_L L_{HGt-1} - def_{HWt} L_{HGt-1} \tag{A.8}$$

$$L_{HCt} = L_{HCt-1} + (1 - CR_{HCt}) NLHC_{Dt} - rep_L L_{HCt-1} - def_{HWt} L_{HCt-1} \tag{A.9}$$

[2] Zezza (2008) also formalises that workers pay rent to the rich households (capitalists).

[3] It's typical in SFC models to use the lagged income or/and wealth to determine consumption (see e.g. Dunz et al. 2021). An alternative way would be to include expected income or/and wealth in consumption (see e.g. Santos and Zezza 2004).

[4] For a similar approach to the firm sector, see Dafermos and Nikolaidi (2022).

$$L_{Ht} = L_{HCt} + L_{HGt} \tag{A.10}$$

The amount of defaulted loans (DL_{HWt}), defined in Eq. (A.11), is a proportion (def_{HWt}) of housing loans. The default rate (def_{HWt}) rises as households become less liquid (see Eq. (A.12)); def_{max} is the maximum default rate. Thus, when cash outflows grow relative to inflows, households' capacity to service their mortgages weakens. Illiquidity is measured by the ratio $illiq_{HWt}$, which sets household cash outflows against cash inflows (see Eq. (A.13)).[5] Cash outflows include mortgage interest and principal repayments on green and conventional housing loans, taxes net of green loan subsidies, consumption spending, and the net cost of housing transactions.

Eq. (A.14) defines dsr_{HWt} as interest and scheduled repayments on green and conventional mortgages relative to disposable income before interest, where int_{LHGt} and int_{LHCt} are the green and conventional mortgage rates, L_{HGt} and L_{HCt} are the green and conventional loan stocks, rep_L is the repayment ratio and Y_{HWt} is net disposable income.[6] Eq. (A.15) reflects the leverage ratio of worker households (lev_{HWt}) which is the ratio of housing loans to the value of houses that they own. H_{WOwnt} denotes the actual total owned occupied houses of workers.

$$DL_{HWt} = def_{HWt} L_{Ht-1} \tag{A.11}$$

$$def_{HWt} = \frac{def_{max}}{1 + def_0 e^{def_1 - def_2 illiq_{HWt-1}}} \tag{A.12}$$

$$\begin{aligned} illiq_{HWt} = {} & \frac{(int_{LHGt-1} + rep_L)L_{HGt-1} + (int_{LHCt-1} + rep_L)L_{HCt-1} + TAX_{HWt} + Rent_t}{W_t + (1 - CR_{HGt})NLHG_{Dt} + (1 - CR_{HCt})NLHC_{Dt}} \\ & + \frac{-int_{SUB}L_{HGt-1} + CO_{HWt} + (H_{WOwnGt} - H_{WOwnGt-1})p_{Ht-1} + (H_{WOwnCt} - H_{WOwnCt-1})p_{Ht-1}}{W_t + (1 - CR_{HGt})NLHG_{Dt} + (1 - CR_{HCt})NLHC_{Dt}} \end{aligned} \tag{A.13}$$

$$dsr_{HWt} = \frac{(int_{LHGt-1} + rep_L)L_{HGt-1} + (int_{LHCt-1} + rep_L)L_{HCt-1}}{Y_{HWt} + int_{LHGt-1}L_{HGt-1} + int_{LHCt-1}L_{HCt-1}} \tag{A.14}$$

$$lev_{HWt} = \frac{L_{Ht}}{p_{Ht} H_{WOwnt}} \tag{A.15}$$

The model distinguishes between the desired and actual housing demand. Eq. (A.16) defines the desired total owned occupied houses of worker households (H_{DWOwnt}) as a function of the debt service ratio (dsr_{HWt}), the growth of house prices (g_{PHt})[7], the growth of the worker population (g_{POPWt}) and the rent rate ($rent_t$).

$$H_{DWOwnt} = H_{WOwnt-1} + (h_{10} - h_{11} dsr_{HWt-1} + h_{12} g_{PHt-1} + h_{13} g_{POPWt-1} + h_{14} rent_{t-1}) H_{WOwnt-1} \tag{A.16}$$

Eq. (A.17) shows the share of green houses in total houses (β_{Ht}). First, a lower green mortgage rate compared to the conventional rate raises the green share. Second, an increase in the interest subsidy (int_{SUB}) increases the green share as well. Eq. (A.18) sets the desired demand of green houses ($H_{DWOwnGt}$) as a share (β_{Ht}) of total desired demand (H_{DWOwnt}). Eq. (A.19) defines the desired demand for conventional houses ($H_{DWOwnCt}$) as the residual from total desired demand (H_{DWOwnt}).

[5] We use a logistic function, on similar lines as Caiani et al. (2016) and Dafermos and Nikolaidi (2022) do for the case of firms.

[6] This follows the definition used by BIS (2023) for the debt service ratio.

[7] A single house price is assumed for green and conventional houses.

$$\beta_{Ht} = \beta_{H0} - \beta_{H1}(int_{LHGt-1} - int_{SUB} - int_{LHCt-1}) \tag{A.17}$$

$$H_{DWOwnGt} = \beta_{Ht} H_{DWOwnt} \tag{A.18}$$

$$H_{DWOwnCt} = H_{DWOwnt} - H_{DWOwnGt} \tag{A.19}$$

The model also distinguishes between the desired amount of new green/conventional housing loans and the actual amount of housing loans. As will be explained below, the actual amount of these loans is determined by the credit rationing process, where banks accept a certain proportion of loan applications. This proportion is positively influenced by both banks' financial position and borrowers' creditworthiness. This means that banks play an active role in shaping actual loans and consequently housing demand.

Since there is credit rationing, the desired amount of demanded houses deviates from the actual amount of demanded houses. Eq. (A.20) defines the actual value of owned occupied houses of worker households. It increases with net saving, given by disposable income (Y_{HWt}) minus consumption (CO_{HWt}) and change in deposits, with new housing loans (ΔL_{Ht}) and with defaulted loans (DL_{HWt}), H_{WOwnt} is the number of houses that worker households own. The actual green houses are a proportion (β_{Ht}) of the total (Eq. (A.21)). The actual conventional houses are the residual shown in Eq. (A.22).

$$H_{WOwnt} = H_{WOwnt-1} + \frac{Y_{HWt} - CO_{HWt} - \Delta D_{HWt} + \Delta L_{Ht} + DL_{HWt}}{p_{Ht}} \tag{A.20}$$

$$H_{WOwnGt} = \beta_{Ht} H_{WOwnt} \tag{A.21}$$

$$H_{WOwnCt} = H_{WOwnt} - H_{WOwnGt} \tag{A.22}$$

Worker households can buy various houses. First, Eqs. (A.23)–(A.25) show how the number of total, green and conventional newly built houses evolves; $H_{WNewOwnOccupt}$ are the newly occupied houses, $H_{WNewOwnOccupGt}$ are newly green occupied houses, and $H_{WNewOwnOccupCt}$ are the newly conventional occupied houses. Second, Eqs. (A.26)-(A.28) show the number of the total, green and conventional existing houses that are bought by worker households that were previously rented; $H_{IRentedSoldt}$ is the total number of the rented houses offered for sale by rentiers and bought by workers while $H_{IRentedSoldGt}$ and $H_{IRentedSoldCt}$ is the green and conventional number of these previously rented houses. Third, the total number of houses that worker households can buy and were previously occupied by the rentier households ($H_{WOwnedOccupt}$) is shown in Eq. (A.29). This equation is an identity derived from Table A.3. Eqs. (A.30)–(A.31) show the green and conventional houses respectively; $H_{WOwnedOccupGt}$ is the green houses that were previously owned by the rentiers and $H_{WOwnedOccupCt}$ are the conventional ones.

$$H_{WNewOwnOccupt} = prop_W H_{Constrt} \tag{A.23}$$

$$H_{WNewOwnOccupGt} = \beta_{Ht} H_{WNewOwnOccupt} \tag{A.24}$$

$$H_{WNewOwnOccupCt} = H_{WNewOwnOccupt} - H_{WNewOwnOccupGt} \tag{A.25}$$

$$H_{IRentedSoldt} = prop_{RentedSold}(H_{WOwnt-1} + H_{IRentt-1}) \tag{A.26}$$

$$H_{IRentedSoldGt} = \beta_{Ht} H_{IRentedSoldt} \tag{A.27}$$

$$H_{IRentedSoldCt} = H_{IRentedSoldt} - H_{IRentedSoldGt} \tag{A.28}$$

$$H_{WOwnedOccupt} = H_{WOwnt} - H_{WOwnt-1} - H_{WNewOwnOccupt} - H_{IRentedSoldt} \tag{A.29}$$

$$H_{WOwnedOccupGt} = \beta_{Ht} H_{WOwnedOccupt} \tag{A.30}$$

$$H_{WOwnedOccupCt} = H_{WOwnedOccupt} - H_{WOwnedOccupGt} \tag{A.31}$$

Worker households then decide on how many houses they need to rent. Eqs. (A.32)–(A.34) show the evolution of the total, green and conventional rented houses. H_{IRentt} is the number of houses that are rented, $H_{Workerst}$ is the number of houses that correspond to workers, $H_{IRentGt}$ is the green rented houses and $H_{IRentCt}$ is the conventional rented houses.

Once workers decide on the total number of rented houses, they choose between newly rented houses and rented houses that were initially owned and occupied by the rentiers. First, Eqs. (A.35)–(A.37) show the number of total, green and conventional houses that are newly rented; $H_{INewRentedt}$ is the number of newly rented houses, $H_{INewRentedGt}$ is the number of newly rented that are green and $H_{INewRentedCt}$ are the newly rented houses that are conventional ones. Second, Eqs. (A.38)–(A.40) show the total, green and conventional number of rented houses that were initially owned and occupied by rentiers. The total number is defined based on the identity derived from the housing stock-flow matrix (see Table A.3). $H_{IOwnOccupRentedt}$ is the number of rented houses that were initially owned and occupied by rentiers, $H_{IOwnOccupRentedGt}$ is the green number of houses rented that were initially owned and occupied by rentiers and $H_{IOwnOccupRentedCt}$ are the conventional number of houses that were owned occupied by rentiers.

$$H_{IRentt} = H_{Workerst} - H_{WOwnt} \tag{A.32}$$

$$H_{IRentGt} = \beta_{Ht} H_{IRentt} \tag{A.33}$$

$$H_{IRentCt} = H_{IRentt} - H_{IRentGt} \tag{A.34}$$

$$H_{INewRentedt} = prop_{NewRented} H_{Constrt} \tag{A.35}$$

$$H_{INewRentedGt} = \beta_{Ht} H_{INewRentedt} \tag{A.36}$$

$$H_{INewRentedCt} = H_{INewRentedt} - H_{INewRentedGt} \tag{A.37}$$

$$\begin{aligned} H_{IOwnOccupRentedt} = {} & H_{IRentt} - H_{IRentt-1} - H_{INewRentedt} + H_{IRentedSoldt} \\ & + H_{IRentedSoldVacantt} \end{aligned} \tag{A.38}$$

$$H_{IOwnOccupRentedGt} = \beta_{Ht} H_{IOwnOccupRentedt} \tag{A.39}$$

$$H_{IOwnOccupRentedCt} = H_{IOwnOccupRentedt} - H_{IOwnOccupRentedGt} \tag{A.40}$$

Eqs. (A.41)–(A.42) show the rent expenditure ($Rent_t$) that worker households pay to the investor households and the rent rate[8] respectively; g_{HDRent} is the growth rate of demanded rented houses, g_{HSRent} is the growth rate of the supplied rented houses and $rent_t$ is the rate that worker households pay to rentiers at the aggregate level.

$$Rent_t = rent_t H_{IRent-1} \tag{A.41}$$

$$rent_t = rent_{t-1} + (rent_0 + rent_1(g_{HDrentt-1} - g_{HSrentt-1}))rent_{t-1} \tag{A.42}$$

1.3. Investor (rentier) households

Eq. (A.43) defines the gross disposable income of investor households (Y_{HIGt}), which consists of the distributed profits from firms (DP_t), the distributed profits from banks (BP_{Dt}), the distributed profits from investment funds (IFP_{Dt}), the distributed profits from money market funds ($MMFP_{Dt}$), along with the interest earned on deposits and government securities; int_D is the interest rate on deposits; D_{HIt} stands for deposits; int_S is the interest rate on government securities;

[8] Zezza (2008) assumes that the rent increases when the income of worker households becomes higher.

SEC_{HIt} are government securities held by investor households.[9]

Eq. (A.44) defines the net disposable income of investor households (Y_{HIt}) as the gross disposable income minus taxes on investor households (TAX_{HIt}). The consumption of investor households (CO_{HIt}), as described in Eq. (A.45), depends on the net disposable income (Y_{HIt}) and the wealth of investor households (V_{HIt}); c_{21} and c_{22} represent the respective propensities to consume out of net disposable income and wealth of investor households. Eq. (A.46) shows the wealth of investor households (V_{HIt}), which comprises the value of houses they demand, deposits (D_{HIt}), government securities (SEC_{HIt}) and shares issued by MMFs (SH_{MMFt}); H_{IOwnGt}, H_{IOwnCt} is investor households demand for their green and conventional owned occupied houses, $H_{IRentGt}$ and $H_{IRentCt}$ is the number of green and conventional rented houses, $H_{Vacantt} - H_{ConstrVacantt}$ are the vacant houses that rentiers own, $H_{Vacantt}$ is the number of total vacant houses and $H_{ConstrVacantt}$ is the number of new constructed houses that are vacant.

$$Y_{HIGt} = DP_t + BP_{Dt} + IFP_{Dt} + MMFP_{Dt} + int_D D_{HIt-1} + int_S SEC_{HIt-1} + Rent_t \tag{A.43}$$

$$Y_{HIt} = Y_{HIGt} - TAX_{HIt} \tag{A.44}$$

$$CO_{HIt} = c_{21} Y_{HIt-1} + c_{22} V_{HIt-1} \tag{A.45}$$

$$\begin{aligned} V_{HIt} = {} & p_{Ht} H_{IOwnGt} + p_{Ht} H_{IOwnCt} + p_{Ht} H_{IRentGt} + p_{Ht} H_{IRentCt} \\ & + p_{Ht}(H_{Vacantt} - H_{ConstrVacantt}) + D_{HIt} + SEC_{HIt} + SH_{MMFt} \end{aligned} \tag{A.46}$$

Investor households accumulate wealth in four different financial and real assets; government securities, (green/conventional) houses, shares issued by MMFs and deposits. The allocation of wealth follows the Tobin-style portfolio allocation approach between these four different assets.[10]

In particular, a proportion of investor households' wealth is invested in all four different financial/real assets (Eq. (A.47) to (A.50N)).[11] This proportion changes in an endogenous way with changes in interest rates in government securities, the rate of return on housing, the rate of return of MMFs and the interest rates in deposits; SEC_{HIt} is government securities, H_{IOwnt} is the demand for houses of investor households; SH_{MMFt} is money market fund shares; D_{HINt} is the notional demand for deposits; r_{SHt} is the rate of return in MMF shares; λ_{10}, λ_{20}, λ_{30} and λ_{40} are the proportions of wealth allocated to different assets. Eq. (A.50N) determines the notional amount of deposits (D_{HINt}). Eq. (A.50) describes the actual amount of deposits since it acts as a buffer variable; deposits adjust based on changes in saving, and changes in government securities, total housing that investor households own, MMF shares and refurbishment expenditure.[12] Eq. (A.51) shows that the rate of return on housing (r_{HIt}) is equal to the rent plus the growth rate of housing prices while Eq. (A.52) shows that the rate of return in MMF shares is equal to the distributed profits of MMFs divided by the number of shares they issue.

$$SEC_{HIt} = (\lambda_{10} + \lambda_{11} int_S + \lambda_{12} r_{HIt-1} + \lambda_{13} r_{SHt-1} + \lambda_{14} int_D + \lambda_{15} \frac{Y_{HIt-1}}{V_{HIt-1}}) V_{HIt-1} \tag{A.47}$$

[9]We assume that MMFs is the only sector that issues shares and are bought by the investor households. In the current model, firms, commercial banks and IFs do not issue shares. Moreover, investor households do not earn rent income from worker households. See Zezza (2008) for an alternative formulation. We have also assumed that investor households do not take out loans. This is a simplification since, according to Albanesi et al. (2022), high-income households took out loans as well during the 2007-8 financial crisis.

[10]The Tobinsque principle relies on the work of Tobin in order to determine the investment in different assets based on the rate of return of each asset and is standard in SFC models (see Godley 1999).

[11]Investor households are the owners of commercial banks and IFs and receive their distributed profits. Investor households hold their capital, but don't invest it (see Godley and Lavoie 2012).

[12]In the simulations, deposits are always positive.

$$H_{IOwnt} = (\lambda_{20} + \lambda_{21} int_S + \lambda_{22} r_{HIt-1} + \lambda_{23} r_{SHt-1} + \lambda_{24} int_D + \lambda_{25} \frac{Y_{HIt-1}}{V_{HIt-1}}) \frac{V_{HIt-1}}{p_{Ht}} \tag{A.48}$$

$$SH_{MMFt} = (\lambda_{30} + \lambda_{31} int_S + \lambda_{32} r_{HIt-1} + \lambda_{33} r_{SHt-1} + \lambda_{34} int_D + \lambda_{35} \frac{Y_{HIt-1}}{V_{HIt-1}}) V_{HIt-1} \tag{A.49}$$

$$D_{HINt} = (\lambda_{40} + \lambda_{41} int_S + \lambda_{42} r_{HIt-1} + \lambda_{43} r_{SHt-1} + \lambda_{44} int_D + \lambda_{45} \frac{Y_{HIt-1}}{V_{HIt-1}}) V_{HIt-1} \tag{A.50N}$$

$$\begin{aligned} &D_{HIt} = D_{HIt-1} + Y_{HIt} - CO_{HIt} - (SEC_{HIt} - SEC_{HIt-1}) - p_{Ht} H_{INewOwnOccupt} \\ &H_{WOwnOccupt} + p_{Ht} H_{IRentedSoldt} - (SH_{MMFt} - SH_{MMFt-1}) - I_{Refurbt} \end{aligned} \tag{A.50}$$

$$r_{HIt} = rent_t + \frac{p_{Ht} - p_{Ht-1}}{p_{Ht-1}} \tag{A.51}$$

$$r_{SHt} = \frac{MMFP_{Dt}}{SH_{MMFt-1}} \tag{A.52}$$

Eqs. (A.53)–(A.54) show the green demand (H_{IOwnGt}) and the conventional demand (H_{IOwnCt}) for houses by rentiers. Eqs. (A.55)–(A.57) show how investor households decide on i) on the number of owned occupied houses that they want to sell to worker households ($H_{WOwnOccupMarkett}$), ii) the rented houses that could be sold ($H_{IRentedSoldMarkett}$), iii) the number of houses that are owned occupied and could be rented ($H_{IOwnOccupRentedMarkett}$) and the types of newly constructed houses they decide to buy. Finally, Eqs. (A.58)–(A.60) shows the number of newly total, green and conventional occupied houses, $H_{INewOwnOccupt}$ are the newly bought occupied houses, $H_{INewOwnOccupGt}$ are the newly bought houses that are green, and $H_{INewOwnOccupCt}$ are the conventional ones.

$$H_{IOwnGt} = \beta_{Ht} H_{IOwnt} \tag{A.53}$$

$$H_{IOwnCt} = H_{IOwnt} - H_{IOwnGt} \tag{A.54}$$

$$H_{WOwnOccupMarkett} = prop_{WExisting} H_{IOwnt} \tag{A.55}$$

$$H_{IRentedSoldMarkett} = prop_{IRented} H_{IOwnt} \tag{A.56}$$

$$H_{IOwnOccupRentedMarkett} = prop_{IOwnOccup} H_{IOwnt} \tag{A.57}$$

$$\begin{aligned} H_{INewOwnOccupt} = &H_{IOwnt} - H_{IOwnt-1} + H_{IOwnOccupRentedt} + H_{WOwnOccupt} \\ &+ H_{IRentedVacantt} + H_{WOwnOccupVacantt} \end{aligned} \tag{A.58}$$

$$H_{INewOwnOccupGt} = \beta_{Ht} H_{INewOwnOccupt} \tag{A.59}$$

$$H_{INewOwnOccupCt} = H_{INewOwnOccupt} - H_{INewOwnOccupGt} \tag{A.60}$$

1.4. Firms

The total output of the economy (Y_t) consists of consumption by worker households (CO_{HWt}), the consumption by investor households (CO_{HIt}), investment by firms (I_t), government consumption expenditures (CO_{GOVt}), green and conventional construction investment ($I_{Constrt}$) and refurbishment investment that converts conventional into green houses ($I_{Refurbt}$), as shown in Eq. (A.61), where $I_{ConstrGt}$ and $I_{ConstrGt}$ are green and conventional construction investment respectively. So in the model, an increase in demand for houses leads to a higher housing supply and construction investment and promotes economic activity.

$$Y_t = CO_{HWt} + CO_{HIt} + I_t + CO_{GOVt} + I_{ConstrGt} + I_{ConstrCt} + I_{Refurbt} \tag{A.61}$$

Eq. (A.62) defines the gross profits of firms (TP_{Gt}), which are calculated as the sales (they are the same with output) minus wages (W_t) and interest payments on both green loans and conventional loans; int_G is the interest rate on green loans and L_{Gt} is the green loans; int_C is the interest rate on conventional loans; L_{Ct} is the conventional loans. Wages, given in Eq. (A.63), are determined as a proportion (s_W) of total output; s_W is the wage share. Eq. (A.64) determines the net profits of firms (TP_t), which are obtained by deducting corporate taxes (TAX_{Ft}) and carbon taxes (TAX_{Ct}) from gross profits of firms. Retained profits (RP_t), as described in Eq. (A.65), represent the portion of net profits that firms choose to retain, calculated as a proportion (s_F) of net profits. Eq. (A.66) defines the distributed profits of firms (DP_t), which are calculated as the difference between net profits and retained profits. Eq. (A.67) calculates firms' rate of profit (r_t) as the ratio of net profits (TP_t) to the capital stock (K_t), Eq. (A.68) and Eq. (A.69) refers to capacity utilisation (u_t) as actual output relative to its potential level and potential output (Y_{pott}) respectively, v is the potential output-to-capital stock.

$$TP_{Gt} = Y_t - W_t - int_G L_{Gt-1} - int_C L_{Ct-1} \tag{A.62}$$

$$W_t = s_W Y_t \tag{A.63}$$

$$TP_t = TP_{Gt} - TAX_{Ft} - TAX_{Ct} \tag{A.64}$$

$$RP_t = s_F TP_{t-1} \tag{A.65}$$

$$DP_t = TP_t - RP_t \tag{A.66}$$

$$r_t = \frac{TP_t}{K_t} \tag{A.67}$$

$$u_t = \frac{Y_t}{Y_{pott}} \tag{A.68}$$

$$Y_{pott} = vK_t \tag{A.69}$$

Eq. (A.70) shows that investment depends on the rate of profit (see, e.g., Blecker 2002) and capacity utilisation. We consider that the rate of profit and capacity utilisation affect investment in a non-linear way in general line with the tradition that draws on Kaldor (1940). As a result of this, once the profit rate and the capacity utilisation are very low or very high, their effects on investment become rather small.[13] Eq. (A.71) shows that the share of green investment to total investment (β_t) changes when the green and conventional interest rates change. Eqs. (A.72)–(A.73) show how green investment (I_{Gt}) and conventional investment (I_{Ct}) are defined. Eqs. (A.74), (A.75) and (A.76) respectively show the value for green capital stock (K_{Gt}), conventional capital stock (K_{Ct}) and total capital stock (K_t).[14] Firms take out green and conventional loans to finance green/conventional housing investment and changes in capital stock (Eq. (A.77)–(A.78)). The total loans are equal to the sum of green and conventional loans (Eq. (A.79)).[15]

$$I_t = \frac{\alpha_{00}}{1 + e^{\alpha_{01} - \alpha_1 u_{t-1} - \alpha_2 r_{t-1}}} K_{t-1} \tag{A.70}$$

$$\beta_t = \beta_0 - \beta_1 (int_G - int_C) \tag{A.71}$$

$$I_{Gt} = \beta_t I_t \tag{A.72}$$

$$I_{Ct} = I_t - I_{Gt} \tag{A.73}$$

$$K_{Gt} = K_{Gt-1} + I_{Gt} \tag{A.74}$$

$$K_{Ct} = K_{Ct-1} + I_{Ct} \tag{A.75}$$

[13]See also Dafermos and Nikolaidi (2022) for a similar investment function.

[14]We assume that there is no depreciation of capital stock. See Dafermos and Nikolaidi (2022) for an investment with depreciation of capital stock.

[15]We assume for simplicity that there is no credit rationing in firms' loans. See Dafermos and Nikolaidi (2022) for credit rationing applied to the firm sector.

$$K_t = K_{Ct} + K_{Gt} \tag{A.76}$$

$$\begin{aligned} L_{Gt} &= L_{Gt-1} + I_{Gt} + I_{ConstrGt} - \beta_t RP_t \\ &- \beta_t p_{Ht}(H_{WNewOwnOccupt} + H_{INewOwnOccupt} + H_{INewRentedt}) \end{aligned} \tag{A.77}$$

$$\begin{aligned} L_{Ct} &= L_{Ct-1} + I_{Ct} + I_{Gt} + I_{ConstrGt} + I_{ConstrCt} - RP_t - (L_{Gt} - L_{Gt-1}) \\ &- p_{Ht}(H_{WNewOwnOccupt} + H_{INewOwnOccupt} + H_{INewRentedt}) \end{aligned} \tag{A.78}$$

$$L_t = L_{Gt} + L_{Ct} \tag{A.79}$$

More houses are built as the demand for houses and house prices increase (Eq. (A.80)), where $New_{Constrt}$ is the new constructed houses.[16] These new constructed houses increase the stock of existing houses (Eq. (A.81)), where $H_{Constrt}$ is the number of constructed houses.[17] The number of the constructed houses are split into green and conventional ones: the number of green houses is a proportion of total houses and the rest are conventional houses (Eqs. (A.82)–(A.83)).

$$New_{Constrt} = (h_{20} + h_{21}\frac{H_{WNewOwnOccupt-1} + H_{INewOwnOccupt-1} + H_{INewRentedt-1}}{H_{Constrt-1}} + h_{22} g_{PHt-1}) H_{Constrt-1} \tag{A.80}$$

$$H_{Constrt} = H_{Constrt-1} + New_{Constrt} \tag{A.81}$$

$$H_{ConstrGt} = \beta_{Ht} H_{Constrt} \tag{A.82}$$

$$H_{ConstrCt} = H_{Constrt} - H_{ConstrGt} \tag{A.83}$$

Investment in constructed houses (in EUR trillion) is the value of the stock of constructed houses (Eq. (A.84)), where $I_{Constrt}$ is the investment in constructed houses and p_{Constr} is the constant price for construction (in EUR trillion /million houses). Eqs. (A.85)–(A.86) shows the green and the conventional investment in construction that takes place; $I_{ConstrGt}$ is the investment in green constructed houses and $I_{ConstrCt}$ is the investment in the conventional constructed houses.

$$I_{Constrt} = p_{Constr} H_{Constrt} \tag{A.84}$$

$$I_{ConstrGt} = \beta_{Ht} I_{Constrt} \tag{A.85}$$

$$I_{ConstrCt} = I_{Constrt} - I_{ConstrGt} \tag{A.86}$$

The model makes a distinction between green residential investment associated with the construction of green houses and residential investment associated with refurbishment that transforms conventional houses into green houses. We implicitly assume that, when β_{Ht} increases, green refurbishment also increases to transform existing conventional houses into green houses. The new number of houses that are refurbished (in million houses) is given by Eq. (A.87), $New_{Refurbt}$ is the new number of refurbished houses. These are the conventional houses that are transformed into green (e.g. the rented houses that are not new and some owner-occupied houses). The stock of refurbished houses ($H_{Refurbt}$) increases by this new number of houses (Eq. (A.88)). The value of refurbished houses ($I_{Refurbt}$) is given by Eq. (A.89), where p_{Refurb} is the constant price of refurbished houses.[18]

[16] Jackson and Victor (2019) and Byrialsen et al. (2024a,b) include other factors in housing investment such as economic activity. Other factors could affect the supply of houses, such as land and construction costs.

[17] We assume that there is no depreciation of the housing capital stock. See Jackson and Victor (2019) and Byrialsen et al. (2024a,b) for a housing market with depreciation of the housing stock.

[18] In the simulations we make sure that p_{Refurb} is lower than the p_{Constr} to capture the higher cost associated with new housing construction.

$$New_{Refurbt} = H_{IRentedSoldGt-1} + H_{WOwnOccupGt-1} + H_{IOwnOccupRentedGt-1} + H_{IRentedVacantGt-1} + H_{IRentedSoldVacantGt-1} + H_{WOwnOccupVacantGt-1} \tag{A.87}$$

$$H_{Refurbt} = H_{Refurbt-1} + New_{Refurbt} \tag{A.88}$$

$$I_{Refurbt} = p_{Refurb} H_{Refurbt} \tag{A.89}$$

Eq. (A.90) defines that the growth rate of the housing prices is affected by the difference between the growth rate of total demanded houses (g_{HDt})[19] and the growth rate of existing houses (g_{Ht}) (see Eatwell et al. 2008 and Nikolaidi 2015).

$$p_{Ht} = p_{Ht-1} + (h_{33} + h_3(g_{HDt-1} - g_{Ht-1}))p_{Ht-1} \tag{A.90}$$

In the model, there are different types of vacant houses (Eqs. (A.91)–(A.103)). Eq. (A.91) defines the vacant new houses ($H_{ConstrVacantt}$). Eq. (A.92) captures the number of rented houses that are vacant and are not sold ($H_{IRentedSoldVacantt}$), while Eq. (A.93) refers to the number of owned houses that are vacant and are not sold ($H_{WOwnOccupVacantt}$). Finally, Eq. (A.94) provides the number of rented houses that are vacant ($H_{IRentedVacantt}$).

$$H_{ConstrVacantt} = H_{Constrt} - H_{WNewOwnOccupt} - H_{INewOwnOccupt} - H_{INewRentedt} \tag{A.91}$$

$$H_{IRentedSoldVacantt} = H_{IRentedSoldMarkett} - H_{IRentedSoldt} \tag{A.92}$$

$$H_{WOwnOccupVacantt} = H_{WOwnOccupMarkett} - H_{WOwnOccupt} \tag{A.93}$$

$$H_{IRentedVacantt} = H_{INewRentedt} + H_{IOwnOccupRentedMarkett} - H_{IOwnOccupRentedt} \tag{A.94}$$

Eqs. (A.95)–(A.100) describe the allocation of the above-mentioned houses between green and conventional. Green houses are a proportion (β_{Ht}) of the total number of houses, while conventional houses are the remaining ones.

$$H_{IRentedSoldVacantGt} = \beta_{Ht} H_{IRentedSoldVacantt} \tag{A.95}$$

$$H_{IRentedSoldVacantCt} = H_{IRentedSoldVacantt} - H_{IRentedSoldVacantGt} \tag{A.96}$$

$$H_{WOwnOccupVacantGt} = \beta_{Ht} H_{WOwnOccupVacantt} \tag{A.97}$$

$$H_{WOwnOccupVacantCt} = H_{WOwnOccupVacantt} - H_{WOwnOccupVacantGt} \tag{A.98}$$

$$H_{IRentedVacantGt} = \beta_{Ht} H_{IRentedVacantt} \tag{A.99}$$

$$H_{IRentedVacantCt} = H_{IRentedVacantt} - H_{IRentedVacantGt} \tag{A.100}$$

Eq. (A.101) shows the overall number of vacant houses, while Eqs. (A.102)–(A.103) shows the number of green and conventional vacant houses. Note that Eq. (A.91) and (A.101) are identities derived from the housing stock-flow matrix (Table A.3).

$$H_{Vacantt} = H_{Vacantt-1} + H_{ConstrVacantt} + H_{IRentedSoldVacantt} + H_{IRentedVacantt} + H_{WOwnOccupVacantt} \tag{A.101}$$

$$H_{VacantGt} = \beta_{Ht} H_{Vacantt} \tag{A.102}$$

[19] The total demand for houses includes the demand of worker and investor households.

$$H_{VacantGt} = \beta_{Ht} H_{Vacantt} \tag{A.103}$$

Eq. (A.104) and Eq. (A.105) show the total housing stock (H_{Totalt}) while Eqs. (A.106)-(A.107) show the total number of green houses ($H_{TotalGt}$) and the total number of conventional houses ($H_{TotalCt}$). Both Eqs. (A.104)–(A.105) are identities taken from the housing stock-flow matrix (Table A.3). We use one of these identities in the simulations, while the other one we use to check that the housing market is consistent. Eqs. (A.106)–(A.107) show the number of total houses that are green and conventional, respectively.

$$H_{Totalt} = H_{Totalt-1} + H_{Constrt} \tag{A.104}$$

$$H_{Totalredt} = H_{WOwnt} + H_{IOwnt} + H_{IRentt} + H_{Vacantt} \tag{A.105}$$

$$H_{TotalGt} = H_{WOwnGt} + H_{IOwnGt} + H_{IRentGt} + H_{VacantGt} \tag{A.106}$$

$$H_{TotalCt} = H_{Totalt} - H_{TotalGt} \tag{A.107}$$

In the model, we link the number of houses to the population of worker and rentier households (Eqs. (A.108)-(A.109)). Eq. (A.108) shows that the number of houses required by worker households ($H_{Workerst}$) is a proportion ($size$) of their population (POP_{Wt}). Similarly, Eq. (A.109) indicates that the number of houses associated with rentier households ($H_{Rentierst}$) is a proportion of the rentier population (POP_R).

$$H_{Workerst} = \frac{POP_{Wt}}{size} \tag{A.108}$$

$$H_{Rentierst} = \frac{POP_R}{size} \tag{A.109}$$

Eq. (A.110) shows a simple wealth inequality index ($WealthIndex_t$) that compares the wealth of the rentiers per person to the wealth of workers per person. The higher the $WealthIndex_t$, the higher the wealth inequality.

$$WealthIndex_t = \frac{V_{HIt}/POP_{Rt}}{V_{HWt}/POP_{Wt}} \tag{A.110}$$

The evolution of the worker and rentier populations over time is described in Eqs. (A.111)–(A.113). Total population (POP_t) grows at an exogenous rate (g_{POP}) according to (A.111). Eq. (A.112) describes the dynamics of worker population (POP_{Wt}) and Eq. (A.113) defines the rentier population as the residual, equal to the difference between the total population and the worker population.

$$POP_t = (1 + g_{POP})POP_{t-1} \tag{A.111}$$

$$POP_{Wt} = prop_{Workers} POP_t \tag{A.112}$$

$$POP_{Rt} = POP_t - POP_{Wt} \tag{A.113}$$

1.5. Commercial banks

Commercial banks hold other financial assets as well, apart from green and conventional firms/worker households loans. They hold government securities and repos that are issued by IFs.[20] They are also the owners of the FVCs and receive distributed profits. They also provide

[20] Commercial banks could potentially buy only a proportion of repos that are issued by IFs while the rest could be bought by other financial institutions (e.g. MMFs).

deposits and get advances from the central bank.

Eq. (A.114) defines the total profits of commercial banks (BP_t), which is equal to the interest on various loans (including housing and firms' loans), interest from government securities and green repos, distributed profits from FVCs ($FVCP_{Dt}$), along with fees received from securitising part of the housing loans (FEE_t)[21] minus the interest expenses on deposits and advances. int_R is the interest rate in repos, $Repo_t$ are the green repos that commercial banks buy, int_{At} is the interest in advances and A_t is the advances of commercial banks. The deposits of commercial banks (D_t) are equal to the deposits held by workers and rentiers (Eq. (A.115)).

Eq. (A.116) shows bank's capital (CAP_t), which increases by undistributed bank profits (BP_{Ut}) and decreases by defaults on non-securitised housing loans (DL_{NHt}).[22] Banks hold part of their profits (Eq. (A.117)) while the rest are distributed to investor households (Eq. (A.118)); BP_{Ut} are the undistributed profits of commercial banks. Eq. (A.119) specifies the defaulted amount of non-securitised housing loans (DL_{NHt}) as a proportion (def_{HWt}) of the sum of non-securitised green housing loans and conventional housing loans.

$$\begin{aligned} BP_t = int_C L_{Ct-1} + int_G L_{Gt-1} + int_{LHGt-1} L_{NHGt-1} + int_{LHCt-1} L_{HCt-1} \\ + int_S SEC_{Bt-1} + int_R Repo_{t-1} + FEE_t + FVCP_{Dt} - int_D D_{t-1} - int_{At} A_{t-1} \end{aligned} \tag{A.114}$$

$$D_t = D_{HWt} + D_{HIt} \tag{A.115}$$

$$CAP_t = CAP_{t-1} + BP_{Ut} - DL_{NHt} \tag{A.116}$$

$$BP_{Ut} = s_B BP_{t-1} \tag{A.117}$$

$$BP_{Dt} = BP_t - BP_{Ut} \tag{A.118}$$

$$DL_{NHt} = def_{HWt}(L_{NHGt-1} + L_{HCt-1}) \tag{A.119}$$

Eq. (A.120) determines the proportion of securitised green housing loans (s_t), which is influenced by an exogenous component (s_0) and by the difference between the green MBS's yield ($yield_{Mt-1}$) and the target MBSs yield ($yield_{MT}$).[23] Eq. (A.121) defines the amount of green securitised housing loans (L_{SHGt}), while Eq. (A.122) shows the non-securitised housing loans as the difference between total green housing loans and securitised green loans.

$$s_t = s_0 - s_1(yield_{Mt-1} - yield_{MT}) \tag{A.120}$$

$$L_{SHGt} = s_t L_{HGt} \tag{A.121}$$

$$L_{NHGt} = L_{HGt} - L_{SHGt} \tag{A.122}$$

Eq. (A.123) defines the amount of high-powered money (HPM_t) as a proportion (h_1) of deposits (D_t). Government securities held by banks (SEC_{Bt}) are also a proportion (h_2) of deposits (Eq. (A.124)). Eq. (A.125) describes the advances that commercial banks take from the central bank to finance their assets. These advances are provided on demand by the central bank.[24]

$$HPM_t = h_1 D_t \tag{A.123}$$

[21] We assume that commercial banks securitise only part of the green housing loans.

[22] We assume for simplicity that defaults take place only within housing loans. Moreover, we assume that commercial banks are not listed on the stock market in order to avoid complications that arise from the effect of changes in the price of shares of banks.

[23] The concept of the target yield stresses that the sponsors of MBSs wanted to ensure that the main buyers of MBSs, the MMFs, were able to purchase highly rated assets (see Acharya et al. 2013; Schroth et al. 2014).

[24] If advances become negative, the government securities bought by banks (SEC_{Bt}) become the buffer variable.

$$SEC_{Bt} = h_2 D_t \tag{A.124}$$

$$\begin{aligned} A_t = {} & A_{t-1} + (HPM_t - HPM_{t-1}) + (L_{Gt} - L_{Gt-1}) + (L_{Ct} - L_{Ct-1}) + (L_{NHGt} - L_{NHGt-1}) \\ & + (L_{HCt} - L_{HCt-1}) + (SEC_{Bt} - SEC_{Bt-1}) + (Repo_t - Repo_{t-1}) - (D_t - D_{t-1}) \\ & - BP_{Ut} + DL_{NHt} \end{aligned} \tag{A.125}$$

Eq. (A.126) defines the leverage ratio of commercial banks (lev_{Bt}) as the ratio of total assets to their capital (CAP_t). The capital adequacy ratio (CAR_t), presented in Eq. (A.127), measures the bank's capital relative to its risk-weighted assets, which include (housing/firm) loans, government securities, high-powered money, and repos, weighted by their respective risk weights; w_L is the weight for loans; w_S is the weight for government securities; w_H is the weight for high-powered money; w_R is the weight for repos.[25]

$$lev_{Bt} = \frac{HPM_t + L_{Ct} + L_{Gt} + L_{NHGt} + L_{HCt} + SEC_{Bt} + Repo_t}{CAP_t} \tag{A.126}$$

$$CAR_t = \frac{CAP_t}{w_L(L_{Ct} + L_{Gt} + L_{NHGt} + L_{HCt}) + w_S SEC_{Bt} + w_H HPM_t + w_R Repo_t} \tag{A.127}$$

As explained earlier, commercial banks provide only an amount of green and conventional housing loans. Eq. (A.128) shows that total credit rationing for household loans (CR_{Ht}) depends negatively on the debt service ratio of worker households and positively on the capital adequacy ratio of commercial banks relative to the minimum capital adequacy ratio (CAR_{min}) determined by the regulatory authority[26] In the baseline scenario, total credit rationing is equal to green and conventional credit rationing. However, credit rationing on green and conventional loans can become different once the yields on MBSs become different (Eqs. (A.129) and (A.130)). We consider that commercial banks will be willing to provide more green mortgages once the yield of MBSs becomes lower. This implies that banks will be able to securitise more green mortgages and transform them, with the help of FVCs into MBSs. $yield_{Mt}$ is the yield on MBSs; $yield_{MT}$ is the target yield for MBSs; CR_{HGt} is the credit rationing on green housing loans; CR_{HCt} is the credit rationing on conventional housing loans.[27]

$$CR_{Ht} = \frac{CR_{max}}{1 + r_0 e^{r_1 - r_2 dsr_{HWt-1} + r_3(CAR_{t-1} - CAR_{min})}} \tag{A.128}$$

$$CR_{HGt} = (1 + l_{H3}(yield_{Mt-1} - yield_{MT}))CR_{Ht} \tag{A.129}$$

$$CR_{HCt} = (1 - l_{H3}(yield_{Mt-1} - yield_{MT}))CR_{Ht} \tag{A.130}$$

The interest rate on the green and conventional housing loans is set as a spread over the policy interest rate, which is determined by the central bank (Eqs. (A.131) and (A.132)) where spr_{HGt} is the lending spread on green housing loans and spr_{HCt} is the lending spread on conventional housing loans. The total spread (spr_{Ht}) depends on the capital adequacy ratio and debt service ratio of worker households (Eq. (A.133)). The same factors that affect total credit rationing also affect the total spread. In the baseline scenario, the total spread of housing loans is the same for green and conventional housing loans. However, a reduction in the yield of green MBSs can reduce the green spread and increase the conventional spread of loans. This is shown in Eqs. (A.134) and (A.135).

[25] See BCBS (2025) for the weights of the different assets.

[26] See Dafermos and Nikolaidi (2022) for a similar formulation for the case of firms. The loan-to-value ratio (or the leverage of worker households) is an alternative indicator that could be used (see e.g. Grovenstein et al. 2005).

[27] During the financial crisis of 2007-8, banks were willing to provide more loans to securitise them, given that there was strong demand (see Deku et al. 2021).

$$int_{LHGt} = spr_{HGt} + int_{At} \tag{A.131}$$

$$int_{LHCt} = spr_{HCt} + int_{At} \tag{A.132}$$

$$spr_{Ht} = spr_{H0} - spr_{H1}(CAR_{t-1} - CAR_{min}) + spr_{H2}dsr_{HWt-1} \tag{A.133}$$

$$spr_{HGt} = (1 + spr_{H3}(yield_{Mt-1} - yield_{MT}))spr_{Ht} \tag{A.134}$$

$$spr_{HCt} = (1 - spr_{H3}(yield_{Mt-1} - yield_{MT}))spr_{Ht} \tag{A.135}$$

1.6. Financial Vehicle Corporations (FVCs)

Eq. (A.136) defines the total profits of FVCs, which consist of interest earned on securitised green mortgages (L_{SHGt}) and government securities (SEC_{FVCt}), minus the securitisation fees (FEE_t) and the coupon payments of green MBSs, where $coupon_{Mt}$ is the coupon rate of green MBSs and m_t is the number of green MBSs that are issued. Eq. (A.137) shows the undistributed profits ($FVCP_{Ut}$), which are a proportion of (s_{FVC}) of the total profits of FVCs. The distributed profits ($FVCP_{Dt}$) are equal to the total profits minus the undistributed profits, as shown in Eq. (A.138).

$$FVCP_t = int_{LHGt-1}L_{SHGt-1} + int_S SEC_{FVCt-1} - FEE_t - coupon_{Mt-1}m_{t-1} \tag{A.136}$$

$$FVCP_{Ut} = s_{FVC}FVCP_{t-1} \tag{A.137}$$

$$FVCP_{Dt} = FVCP_t - FVCP_{Ut} \tag{A.138}$$

Eq. (A.139) defines the coupon rate of green MBSs, which is determined by the yield on green MBSs ($yield_{Mt}$) multiplied by the par value of green MBSs ($\bar{p}_M$). The yield of green MBSs, as shown in Eq. (A.140), is calculated as the ratio of the coupon rate to the price of green MBSs (p_{Mt}).[28] The higher the demand for these bonds, the higher the price and as expected the lower the yield of these bonds. Eq. (A.141) determines the fees that FVCs pay to commercial banks. These fees are calculated as a proportion (fee) of the securitised green mortgages (L_{SHGt}).

$$coupon_{Mt} = yield_{Mt-1}\bar{p}_M \tag{A.139}$$

$$yield_{Mt} = \frac{coupon_{Mt}}{p_{Mt}} \tag{A.140}$$

$$FEE_t = feeL_{SHGt-1} \tag{A.141}$$

Eq. (A.142) shows the change in the capital of FVCs (K_{FVCt}), which consists of the undistributed profits of FVCs minus the default on securitised green housing loans (DL_{FVCt}). The defaulted green securitised housing loans is a proportion (def_{HWt}) of the securitised green housing loans (Eq. (A.143)). Eq. (A.144) shows the change in the number of green MBSs (m_t) that FVCs decide to issue. The change in the number of green MBSs becomes higher when the securitised green mortgages become higher.[29] Eq. (A.145) represents the value of the total green MBSs (M_t), which comprise those held by IFs (M_{IFt}) and MMFs (M_{MMFt}). Eq. (A.146) shows the price of green MBSs, calculated as the ratio of their total value of green MBSs to the total number of green MBSs issued (m_t).[30] Eq. (A.147) shows the change in government securities held by FVCs (SEC_{FVCt}). FVCs decide to hold more government securities when their undistributed profits ($FVCP_{Ut}$) plus the new value of green MBSs issued are higher than the change in securitised green housing loans and defaulted loans experienced by FVCs.

[28] See Dafermos and Nikolaidi (2022) for a similar formulation for the case of corporate (conventional/green) bonds.

[29] Combining Eq. (A.8) and Eq. (A.144) we can see that the default rate is cancelled out and does not affect the number of bonds issued.

[30] It is assumed that there is equilibrium in the market of green MBSs.

$$K_{FVCt} = K_{FVCt-1} + FVCP_{Ut} - DL_{FVCt} \tag{A.142}$$

$$DL_{FVCt} = def_{HWt} L_{SHGt-1} \tag{A.143}$$

$$m_t = m_{t-1} + (L_{SHGt} - L_{SHGt-1}) + DL_{FVCt} \tag{A.144}$$

$$M_t = M_{IFt} + M_{MMFt} \tag{A.145}$$

$$p_{Mt} = \frac{M_t}{m_t} \tag{A.146}$$

$$SEC_{FVCt} = SEC_{FVCt-1} + FVCP_{Ut} + \bar{p}_M(m_t - m_{t-1}) - (L_{SHGt} - L_{SHGt-1}) - DL_{FVCt} \tag{A.147}$$

1.7. Investment Funds (IFs)

IFs hold government securities and green MBSs on the asset side of their balance sheet. They issue repurchase agreements (repos) to fund their activities (they also hold capital). Eq. (A.148) defines the total profits of IFs (IFP_t), which are equal to the coupon payments received from green MBSs plus interest earned on government securities, minus the interest paid on repos; SEC_{IFt} is the government securities held by IFs. Eq. (A.149) shows the undistributed profits of IFs (IFP_{Ut}), which are a proportion (s_{IF}) of their total profits. The distributed profits (IFP_{Dt}) are calculated as the total profits minus the undistributed profits, as shown in Eq. (A.150). IFs hold capital (K_{IFt}) which increases by their undistributed profits (Eq. (A.151)).

$$IFP_t = coupon_{Mt-1} m_{IFt-1} + int_S SEC_{IFt-1} - int_R Repo_{t-1} \tag{A.148}$$

$$IFP_{Ut} = s_{IF} IFP_{t-1} \tag{A.149}$$

$$IFP_{Dt} = IFP_t - IFP_{Ut} \tag{A.150}$$

$$K_{IFt} = K_{IFt-1} + IFP_{Ut} \tag{A.151}$$

IFs buy green MBSs since they can be used as collateral when they issue repos. Eq. (A.152) defines the value of green MBSs held by IFs (M_{IFt}), which is equal to their capital divided by thehaircut ($haircut_t$).[31] The more capital the IFs have, the higher the value of MBSs they would like to buy. Moreover, the lower the haircut of the MBSs the more willing the IFs are to buy green MBSs. The haircut, as described in Eq. (A.153), is determined by a fixed component (ϵ_0) and a variable component that depends on the difference between the green mortgage yield ($yield_{Mt}$) and the target market yield ($yield_{MT}$).[32] By combining Eq. (A.152) and Eq. (A.153), we can see that the lower the yield of green MBSs, the lower the haircut of repos and the more willing the IFs are to buy green MBSs. Eq. (A.154) shows the number of green MBSs held by IFs, which is obtained by dividing their market value (M_{IFt}) by the market price (p_{Mt}).

$$M_{IFt} = \frac{K_{IFt-1}}{haircut_t} - SEC_{IFt} \tag{A.152}$$

$$haircut_t = \epsilon_0 + \epsilon_1(yield_{Mt-1} - yield_{MT}) \tag{A.153}$$

$$m_{IFt} = \frac{M_{IFt}}{p_{Mt}} \tag{A.154}$$

Eq. (A.155)) shows that the government securities bought by IFs are a proportion of total government securities (SEC_t). Once IFs decide about the green MBBs and government securities that

[31] This is generally in line with the argument of Adrian and Shin (2010) that shadow banks (e.g. security broker-dealers) had a procyclical leverage ratio during the financial crisis of 2007-8.

[32] By definition, the haircut is the difference between the initial market value of an asset and the purchase price paid for that asset at the start of a repo (see e.g. ICMA 2025).

they buy, then they decide the amount of repos they issue (Eq. (A.156)). Eq. (A.157) defines the leverage ratio of IFs, which is calculated as the ratio of total assets—comprising the green MBss and government securities—to their capital. So an increase in the price of green MBSs, increases the leverage of IFs and their willingness to issue repos.

$$SEC_{IFt} = h_{IF} SEC_t \tag{A.155}$$

$$Repo_t = Repo_{t-1} + \bar{p}_M(m_{IFt} - m_{IFt-1}) + (SEC_{IFt} - SEC_{IFt-1}) - IFP_{Ut} \tag{A.156}$$

$$lev_{IFt} = \frac{p_{Mt} m_{IFt} + SEC_{IFt}}{K_{IFt}} \tag{A.157}$$

1.8. Money Market Funds (MMFs)

Eq. (A.158) defines the total profits of MMFs ($MMFP_t$), which consist of coupon payments received from green MBSs and interest earned on government securities (SEC_{MMFt}). Eq. (A.159) shows the undistributed profits ($MMFP_{Ut}$), which are a proportion of (s_{MMF}) of the total profits of MMFs. Subsequently, the distributed profits ($MMFP_{Dt}$) are calculated as the total profits minus the undistributed profits, as shown in Eq. (A.160). Eq. (A.161) describes the change in the capital of MMFs (K_{MMFt}), which increases with undistributed profits.

$$MMFP_t = coupon_{Mt-1} m_{MMFt-1} + int_S SEC_{MMFt-1} \tag{A.158}$$

$$MMFP_{Ut} = s_{MMF} MMFP_{t-1} \tag{A.159}$$

$$MMFP_{Dt} = MMFP_t - MMFP_{Ut} \tag{A.160}$$

$$K_{MMFt} = K_{MMFt-1} + MMFP_{Ut} \tag{A.161}$$

MMFs choose between two assets: green MBSs and government securities. They do so by relying upon Tobin's portfolio allocation. The value of green MBSs held by MMFs (M_{MMFt}) is defined in Eq. (A.162), which is a proportion of the shares that MMFs issue (SH_{MMFt}). This proportion is endogenous: it depends on the yield on green MBSs ($yield_{Mt}$) and the interest rate on government securities (int_S). Accordingly, the notional amount of government securities is defined in Eq. (A.162N).[33] Eq. (A.163) outlines the government securities of MMFs, which act as a buffer variable. The number of green MBSs held by MMFs is represented in Eq. (A.164), which is calculated by dividing their total market value (M_{MMFt}) by the price (p_{Mt}). Eq. (A.165) defines the leverage ratio of MMFs (lev_{MMFt}), which is equal to green MBSs and government securities (i.e. their total assets) to the shares that they issue.

$$M_{MMFt} = (\gamma_{10} + \gamma_{11} yield_{Mt-1} + \gamma_{12} int_S) SH_{MMFt-1} \tag{A.162}$$

$$SEC_{MMFNt} = (\gamma_{20} + \gamma_{21} yield_{Mt-1} + \gamma_{22} int_S) SH_{MMFt-1} \tag{A.162N}$$

$$\begin{aligned} SEC_{MMFt} = {} & SEC_{MMFt-1} + (SH_{MMFt} - SH_{MMFt-1}) - \bar{p}_M(m_{MMFt} - m_{MMFt-1}) \\ & + MMFP_{Ut} \end{aligned} \tag{A.163}$$

$$m_{MMFt} = \frac{M_{MMFt}}{p_{Mt}} \tag{A.164}$$

$$lev_{MMFt} = \frac{p_M m_{MMFt} + SEC_{MMFt}}{SH_{MMFt}} \tag{A.165}$$

[33] The parameters in the portfolio choice equations satisfy the horizontal, vertical and symmetry constraints.

1.9. Government sector

Eq. (A.166) shows the government net saving (GNS_t) which is the difference between the government's revenues and expenditures. The government revenues consist of taxes (TAX_t) and central bank profits (CBP_t) while the government spending consists of government consumption, interest loans subsidies and interest on securities; SEC_t are the securities issued by the government. According to Eq. (A.167) the government issues securities when the government net saving is negative. Government consumption spending is a proportion (gov_C) of output (Eq. (A.168)). Eqs. (A.169), (A.170), (A.171) and (A.172) show respectively worker households' taxes (TAX_{HWt}), investor households' taxes (TAX_{HIt}), taxes on firms' profits (TAX_{Ft}), and carbon taxes that the firms have to pay (TAX_{Ct}).[34] Carbon taxes are a proportion (τ_C) of other emissions.[35] Total taxes are equal to the taxes that the government collects from worker households, investor households and firms (Eq. (A.173)).

$$GNS_t = TAX_t + CBP_t - CO_{GOVt} - int_{SUB} L_{HGt-1} - int_S SEC_{t-1} \tag{A.166}$$

$$SEC_t = SEC_{t-1} - GNS_t \tag{A.167}$$

$$CO_{GOVt} = gov_C Y_{t-1} \tag{A.168}$$

$$TAX_{HWt} = \tau_{HW} Y_{HWGt-1} \tag{A.169}$$

$$TAX_{HIt} = \tau_{HI} Y_{HIGt-1} \tag{A.170}$$

$$TAX_{Ft} = \tau_F TP_{Gt-1} \tag{A.171}$$

$$TAX_{Ct} = \tau_C EMIS_{Ot-1} \tag{A.172}$$

$$TAX_t = TAX_{HWt} + TAX_{HIt} + TAX_{Ft} + TAX_{Ct} \tag{A.173}$$

1.10. Central bank

Eq. (A.174) shows the central bank's net profits, which are composed of interest payments on advances and interests on the central bank's securities; SEC_{CBt} are the government securities held by the central bank. These government securities held by the central bank are equal to the government securities that are not held by households, commercial banks, FVCs, IFs and MMFs (Eq. (A.175)). Eq. (A.176) is the redundant equation of the model.[36] The wealth of the central bank (V_{CBt}) is equal to the advances, the government securities held by the central bank minus high-powered money (Eq. (A.177)). Eq (A.178) shows the interest rate on advances, which increases or decreases based on the greenness or dirtiness of the banks' mortgage portfolio (see van't Klooster and van Tilburg 2020; Krebel and van Lerven 2022; Jourdan et al. 2024).[37]

$$CBP_t = int_{At-1} A_{t-1} + int_S SEC_{CBt-1} \tag{A.174}$$

$$SEC_{CBt} = SEC_t - SEC_{HIt} - SEC_{Bt} - SEC_{FVCt} - SEC_{IFt} - SEC_{MMFt} \tag{A.175}$$

$$SEC_{CBredt} = SEC_{CBt-1} + (HPM_t - HPM_{t-1}) - (A_t - A_{t-1}) \tag{A.176}$$

$$V_{CBt} = A_t + SEC_{CBt} - HPM_t \tag{A.177}$$

[34] In 2027, the European Union will apply an explicit carbon price to fuels used in buildings and road transport through a separate emissions trading system known as EU ETS2 (see e.g. European Commission 2025). In our future work, we could investigate the incorporation of carbon taxes in the household sector.

[35] In the simulations, τ_C is considered constant, but could become endogenous (see e.g. NGFS 2025).

[36] In our simulations, we always make sure that the redundant equation is satisfied.

[37] In the current simulations, it is assumed that there is no change in the int_{max} and int_{min} by the central bank to promote green policies.

$$int_{At} = int_{ref} + (int_{max} - int_{ref})\frac{L_{HCt}}{L_{Ht}} - (int_{ref} - int_{min})\frac{L_{HGt}}{L_{Ht}} \quad \text{(A.178)}$$

1.11. Emissions

Eq. (A.179) shows that housing emissions ($EMIS_{Ht}$) depend on the housing stock. CI_{Ht} is the carbon intensity of the housing stock (H_{Total}). This intensity can become lower as the total green houses increase compared to total conventional houses (Eq. (A.180)). Eq. (A.181) defines the rest of carbon emissions ($EMIS_{Ot}$) as a function of output.[38] CI_{Ot} is the carbon intensity that corresponds to the rest of the emissions. This intensity becomes lower when firms invest more in green capital compared to conventional capital (Eq. (A.182)).

$$EMIS_{Ht} = CI_{Ht}H_{Totalt} \quad \text{(A.179)}$$

$$CI_{Ht} = CI_{Hmax} - \frac{CI_{Hmax} - CI_{Hmin}}{1 + e^{-\kappa_{CIH}(H_{TotalGt-1}/H_{TotalCt-1} - 1/(H_{TotalGt-1}/H_{TotalCt-1}) - c_{CIH})}} \quad \text{(A.180)}$$

$$EMIS_{Ot} = CI_{Ot}Y_t \quad \text{(A.181)}$$

$$CI_{Ot} = CI_{Omax} - \frac{CI_{Omax} - CI_{Omin}}{1 + e^{-\kappa_{CIO}(K_{Gt-1}/K_{Ct-1} - 1/(K_{Gt-1}/K_{Ct-1}) - c_{CIO})}} \quad \text{(A.182)}$$

[38] An increase in housing investment (the flow) increases other emissions while an increase in houses (the stock) increases housing emissions.

2. Symbols, data sources and values for variables and parameters

Table A.4: Symbols and initial values for endogenous variables (baseline scenario)

Symbol	Description	Variable category	Initial value	Source/remarks
A	Advances (EUR trillion)	Model-constrained	5.591	Calculated from Eq. (191)
BP	Profit of the banks (EUR trillion)	Model-constrained	0.2776	Calculated from Eq. (114)
BP_D	Distributed profit of the banks (EUR trillion)	Model-constrained	0.083	Calculated from Eq. (118)
BP_U	Undistributed profit of the banks (EUR trillion)	Model-constrained	0.1946	Calculated from Eq. (117)
CAP	Capital of banks (EUR trillion)	Model-constrained	2.0056	Calculated from Eq. (126)
CAR	Capital adequacy ratio	Model-constrained	0.116	Calculated from Eq. (127)
CBP	Central bank profits (EUR trillion)	Model-constrained	0.2473	Calculated from Eq. (175)
CI_H	Carbon intensity of houses (GtCO2/Million)	Model-constrained	0.0042	Calculated from Eq. (180)
CI_O	Carbon intensity of other emissions (GtCO2/EUR trillion)	Model-constrained	0.1091	Calculated from Eq. (182)
CO_{GOV}	Government expenditure (EUR trillion)	Free	3.0639	The proportion of government expenditure in GDP is based on Eurostat
CO_{HI}	Consumption of investor households' (EUR trillion)	Model-constrained	2.4152	Calculated from Eq. (61)
CO_{HW}	Consumption of worker households (EUR trillion)	Model-constrained	5.9011	Calculated from Eq. (20)
$coupon_M$	Green MBSs coupon payments	Model-constrained	0.0384	Calculated from Eq. (139)
CR_H	Degree of total credit rationing on housing loans	Model-constrained	0.2	Calculated from Eq. (128)
CR_{HC}	Degree of conv. credit rationing on housing loans	Model-constrained	0.2	Calculated from Eq. (130)
CR_{HG}	Degree of green credit rationing on housing loans	Model-constrained	0.2	Calculated from Eq. (129)
D	Deposits (EUR trillion)	Free	21.885	Selected from a reasonable range of values
D_{HI}	Deposits held by investor households (EUR trillion)	Model-constrained	19.6965	Calculated from Eq. (115)
D_{HIN}	Deposits held by investor households (EUR trillion)	Free	19.6965	Selected from a reasonable range of values
D_{HW}	Deposits held by worker households (EUR trillion)	Free	2.1885	Selected from a reasonable range of values
def_{HW}	Default rate on housing loans	Free	0.02	Based on Eurostat
DL_{FVC}	Amount of defaulted loans, FVCs (EUR trillion)	Model-constrained	0.0049	Calculated from Eq. (144)
DL_{HW}	Amount of defaulted loans (EUR trillion)	Model-constrained	0.1602	Calculated from Eq. (11)
DL_{NH}	Amount of defaulted loans com. banks (EUR trillion)	Model-constrained	0.1553	Calculated from Eq. (119)
DP	Distributed profits (EUR trillion)	Model-constrained	3.8742	Calculated from Eq. (66)
dsr_{HW}	Debt service ratio of worker households	Model-constrained	0.1836	Calculated from Eq. (14)
$EMIS_H$	Housing emissions (GtCO2), 0.33 EEA proportion of building emissions	Free	0.7841	Based on NGFS (2025) and EEA (2025)
$EMIS_O$	Other emissions (GtCO2), 0.33 EEA proportion of building emissions	Free	1.5919	Based on NGFS (2025) and EEA (2025)
FEE	Fee (EUR trillion)	Model-constrained	0.0014	Calculated from Eq. (142)
$FVCP$	Profit of the FVCs (EUR trillion)	Model-constrained	0.0279	Calculated from Eq. (ES)
$FVCP_D$	Distributed profit of the FVCs (EUR trillion)	Model-constrained	5e-04	Calculated from Eq. (138)
$FVCP_U$	Undistributed profit of the FVCs (EUR trillion)	Model-constrained	0.0274	Calculated from Eq. (137)

GNS	Government net saving (EUR trillion)	Model-constrained	-0.2489	Calculated from Eq. (167)
H_{Constr}	Number of constructed houses (Million houses)	Model-constrained	3.6788	Calculated from Eq. (104)
$H_{ConstrC}$	Conv. new houses (Million houses)	Model-constrained	2.428	Calculated from Eq. (83)
$H_{ConstrG}$	Green new houses (Million houses)	Model-constrained	1.2508	Calculated from Eq. (82)
$H_{ConstrVacant}$	Vacant new houses (Million houses)	Model-constrained	0.2755	Calculated from Eq. (91)
H_{DWOwn}	Number of houses workers desire to buy (Million houses)	Model-constrained	39.5241	Calculated from Eq. (10),(8),(9), (187) and (188)
H_{DWOwnC}	Number of conv. houses workers desire to buy (Million houses)	Model-constrained	26.0859	Calculated from Eq. (19)
H_{DWOwnG}	Number of green houses workers desire to buy (Million houses)	Model-constrained	13.4382	Calculated from Eq. (18)
$H_{INewOwnOccup}$	Number of new own-occupied houses by rentiers (Million houses)	Model-constrained	2.9736	Calculated from Eq. (58)
$H_{INewOwnOccupC}$	Number of new conv. own-occupied houses by rentiers (Million houses)	Model-constrained	1.9626	Calculated from Eq. (60)
$H_{INewOwnOccupG}$	Number of new green own-occupied houses by rentiers (Million houses)	Model-constrained	1.011	Calculated from Eq. (59)
$H_{INewRented}$	Number of new rented houses (Million houses)	Model-constrained	0.2036	Calculated from Eq. (38) and Eq. (92)
$H_{INewRentedC}$	Number of new conv. rented houses (Million houses)	Model-constrained	0.1344	Calculated from Eq. (37)
$H_{INewRentedG}$	Number of green new rented houses (Million houses)	Model-constrained	0.0692	Calculated from Eq. (36)
H_{IOwn}	Number of houses investors own (Million houses)	Free	66.5739	Selected from a reasonable range of values
H_{IOwnC}	Number of conv. own-occupied houses by rentiers (Million houses)	Model-constrained	43.9388	Calculated from Eq. (54)
H_{IOwnG}	Number of green own-occupied houses by rentiers (Million houses)	Model-constrained	22.6351	Calculated from Eq. (53)
$H_{IOwnOccupRented}$	Number of owned houses that are rented (Million houses)	Free	0.8931	Selected from a reasonable range of values
$H_{IOwnOccupRentedC}$	Number of conv. rented houses that were own-occupied by rentiers (Million houses)	Model-constrained	0.5894	Calculated from Eq. (40)
$H_{IOwnOccupRentedG}$	Number of green rented houses that were own-occupied by rentiers (Million houses)	Model-constrained	0.3036	Calculated from Eq. (39)
$H_{IOwnOccupRentedMarket}$	Number of own-occupied houses by rentiers for renting (Million houses)	Model-constrained	0.7989	Calculated from Eq. (57)
H_{IRent}	Total number of rented houses (Million houses)	Free	52.5329	Based on ECB
H_{IRentC}	Number of conv. rented houses (Million houses)	Model-constrained	34.6717	Calculated from Eq. (34)
$H_{IRentedSold}$	Number of rented houses that are sold (Million houses)	Model-constrained	0.0645	Calculated from Eq. (92)
$H_{IRentedSoldC}$	Number of conv. rented houses that were sold (Million houses)	Model-constrained	0.0426	Calculated from Eq. (28)
$H_{IRentedSoldG}$	Number of green rented houses that were sold (Million houses)	Model-constrained	0.0219	Calculated from Eq. (27)

$H_{IRentedSoldMarket}$	Number of rented houses by rentiers for selling (Million houses)	Model-constrained	0.0666	Calculated from Eq. (56)
$H_{IRentedSoldVacant}$	Number of rented houses that are vacant and are not sold (Million houses)	Free	0.0021	Based on ECB
$H_{IRentedSoldVacantC}$	Number of conv. rented houses that are vacant (Million houses)	Model-constrained	0.0014	Calculated from Eq. (94)
$H_{IRentedSoldVacantG}$	Number of green rented houses that are vacant (Million houses)	Model-constrained	7e-04	Calculated from Eq. (93)
$H_{IRentedVacant}$	Number of rented houses that are vacant (Million houses)	Model-constrained	0.1094	Calculated from Eq. (98)
$H_{IRentedVacantC}$	Number of conv. rented houses that are vacant (Million houses)	Model-constrained	0.0722	Calculated from Eq. (100)
$H_{IRentedVacantG}$	Number of green rented houses that are vacant (Million houses)	Model-constrained	0.0372	Calculated from Eq. (99)
H_{IRentG}	Number of green rented houses (Million houses)	Model-constrained	17.8612	Calculated from Eq. (33)
H_{Refurb}	Number of refurbished houses (Million houses)	Model-constrained	29.4911	Calculated from Eq. (88)
$H_{Rentiers}$	Number of houses rentiers live in (Million houses)	Model-constrained	60.5217	Calculated from Eq. (109)
H_{Total}	Total number of houses (Million houses)	Model-constrained	187.6174	Calculated from Eq. (105)
H_{TotalC}	Total number of conv. houses (Million houses)	Model-constrained	123.8275	Calculated from Eq. (185)
H_{TotalG}	Total number of green houses (Million houses)	Model-constrained	63.7899	Calculated from Eq. (184)
$H_{Totalred}$	Total number of houses (Million houses)	Free	187.6174	Based on ECB
H_{Vacant}	Total number of vacant houses (Million houses)	Model-constrained	30.2609	Calculated from Eq. (101)
$H_{VacantC}$	Number of conv. vacant houses (Million houses)	Model-constrained	19.9722	Calculated from Eq. (103)
$H_{VacantG}$	Number of green vacant houses (Million houses)	Model-constrained	10.2887	Calculated from Eq. (102)
$H_{WNewOwnOccup}$	Number of new own-occupied houses of workers (Million houses)	Model-constrained	0.2261	Calculated from Eq. (29)
$H_{WNewOwnOccupC}$	Number of new conv. houses workers buy (Million houses)	Model-constrained	0.1492	Calculated from Eq. (25)
$H_{WNewOwnOccupG}$	Number of new green houses workers buy (Million houses)	Model-constrained	0.0769	Calculated from Eq. (24)
$H_{Workers}$	Number of houses worker live in (Million houses)	Model-constrained	90.7826	Calculated from Eq. (108)
H_{WOwn}	Number of houses workers own (Million houses)	Model-constrained	38.2497	Calculated from Eq. (32)
H_{WOwnC}	Number of conv. houses workers buy (Million houses)	Model-constrained	25.2448	Calculated from Eq. (22)
H_{WOwnG}	Number of green houses workers buy (Million houses)	Model-constrained	13.0049	Calculated from Eq. (21)
$H_{WOwnOccup}$	Number of houses workers own occupy (Million houses)	Model-constrained	0.4594	Calculated from Eq. (95)
$H_{WOwnOccupC}$	Number of new conv. own-occupied houses of workers (Million houses)	Model-constrained	0.3032	Calculated from Eq. (31)
$H_{WOwnOccupG}$	Number of new green own-occupied houses of workers (Million houses)	Model-constrained	0.1562	Calculated from Eq. (30)
$H_{WOwnOccupMarket}$	Number of own-occupied houses by rentiers for selling (Million houses)	Model-constrained	0.6657	Calculated from Eq. (55)
$H_{WOwnOccupVacant}$	Number of owned houses that are vacant and are not sold (Million houses)	Free	0.2064	Based on ECB

$H_{WOwnOccupVacantC}$	Conv. vacant workers own occupied houses (Million houses)	Model-constrained	0.1362	Calculated from Eq. (97)
$H_{WOwnOccupVacantG}$	Number of green vacant houses own occupied houses (Million houses)	Model-constrained	0.0702	Calculated from Eq. (96)
$haircut$	Haircut on repos	Model-constrained	0.2451	Calculated from Eq. (153)
HG_{HC}		Model-constrained	0.5152	Calculated from Eq. (201)
HPM	High-powered money (EUR trillion)	Free	8.6081	The high-powered money in GDP is based on Eurostat
I	Investment (EUR trillion)	Free	2.349	The proportion of total investment in GDP is based on Eurostat
I_C	Conv. investment of firms (EUR trillion)	Model-constrained	1.4768	Calculated from Eq. (73)
I_{Constr}	Investment in new houses (EUR trillion)	Free	0.3529	The proportion of investment in construction in GDP is based on Eurostat and EOS (2024)
$I_{ConstrC}$	Investment in new conv. houses (EUR trillion)	Model-constrained	0.2329	Calculated from Eq. (86)
$I_{ConstrG}$	Investment in new green houses (EUR trillion)	Model-constrained	0.12	Calculated from Eq. (85)
I_G	Green investment (EUR trillion)	Free	0.8722	Green investment refers to renewable energy investment based on NGFS (2025), 0.89 is the exchange rate
I_{Refurb}	Investment in refurbishment (EUR trillion)	Free	0.5079	The proportion of investment in dwellings in GDP is based on Eurostat
IFP	Profit of the IFs (EUR trillion)	Model-constrained	0.0026	Calculated from Eq. (149)
IFP_D	Distributed profit of the IFs (EUR trillion)	Model-constrained	0.001	Calculated from Eq. (151)
IFP_U	Undistributed profit of the IFs (EUR trillion)	Model-constrained	0.0016	Calculated from Eq. (150)
$illiq_{HW}$	Worker households' illiquidity ratio	Model-constrained	1	Calculated from Eq. (13)
int_A	Interest rate on advances	Model-constrained	0.03	Calculated from Eq. (179)
int_{LHC}	Interest rate on conv. housing loans	Free	0.04	Based on ECB
int_{LHG}	Interest rate on green housing loans	Free	0.04	Based on ECB
K	Capital stock of firms (EUR trillion)	Model-constrained	119.7985	Calculated from Eq. (76)
K_C	Conv. capital of firms (EUR trillion)	Model-constrained	75.3163	Calculated from Eq. (75)
K_{FVC}	Capital of FVCs (EUR trillion)	Model-constrained	1.1462	Calculated from Eq. (148)
K_G	Green capital of firms (EUR trillion)	Model-constrained	44.4822	Calculated from Eq. (74)
K_{IF}	Capital of IFs (EUR trillion)	Model-constrained	0.0817	Calculated from Eq. (158)
K_{MMF}	Capital of MMFs (EUR trillion)	Model-constrained	0.4406	Calculated from Eq. (164)
KG_{KC}		Model-constrained	0.5906	Calculated from Eq. (202)
L	Total loans (EUR trillion)	Free	9.3376	The loans to the non-financial corporations in GDP is based on Eurostat
L_C	Firms conv. loans (EUR trillion)	Model-constrained	5.8705	Calculated from Eq. (79)
L_G	Green loans (EUR trillion)	Free	3.4671	Selected from a reasonable range of values
L_H	Household debt, consolidated including Non-profit institutions serving households (NPISH) (EUR trillion)	Free	8.1704	The loans to the households in percent of GDP is based on Eurostat
L_{HC}	Conv. housing loans (EUR trillion)	Model-constrained	5.3925	Calculated from Eq. (10)

L_{HG}	Green housing loans (EUR trillion)	Free	2.7779	Selected from a reasonable range of values
L_{NHG}	Non-securitised green housing loans (EUR trillion)	Model-constrained	2.5279	Calculated from Eq. (122)
L_{SHG}	Securitised green housing loans (EUR trillion)	Model-constrained	0.25	Calculated from Eq. (121)
lev	Firms' leverage ratio	Model-constrained	0.0779	Calculated from Eq. (193)
lev_B	Leverage ratio of banks	Free	14.7	Based on Eurostat
lev_{HW}	Leverage ratio of worker households	Model-constrained	0.9709	Calculated from Eq. (15)
lev_{IF}	Leverage ratio of IFs	Free	4	Based on ECB
lev_{MMF}	Leverage ratio of MMFs	Free	2.2	Based on ECB
m	Number of green MBSs issued (Million)	Model-constrained	0.5	Calculated from Eq. (145)
M	Value of the green MBSs (EUR trillion)	Model-constrained	0.5	Calculated from Eq. (147)
m_{IF}	Number of green MBSs owned by IFs (Million)	Model-constrained	0.2	Calculated from Eq. (155)
M_{IF}	Green MBSs held by IFs (EUR trillion)	Free	0.2	Selected from a reasonable range of values
m_{MMF}	Number of gren MBSs held by MMFs (Million)	Model-constrained	0.3	Calculated from Eq. (165)
M_{MMF}	Value of green MBSs held by MMFs (EUR trillion)	Model-constrained	0.3	Calculated from Eq. (146)
$MMFP$	Profit of the MMFs (EUR trillion)	Model-constrained	0.0252	Calculated from Eq. (159)
$MMFP_D$	Distributed profit of the MMFs (EUR trillion)	Model-constrained	0.0166	Calculated from Eq. (161)
$MMFP_U$	Undistributed profit of the MMFs (EUR trillion)	Model-constrained	0.0086	Calculated from Eq. (160)
New_{Constr}	Number of new houses constructed (Million houses)	Model-constrained	0.0721	Calculated from Eq. (81)
New_{Refurb}	Number of refurbished houses (Million houses)	Model-constrained	0.5783	Calculated from Eq. (87)
$NLHC_D$		Model-constrained	0.9252	Calculated from Eq. (188)
$NLHG_D$		Model-constrained	0.4766	Calculated from Eq. (187)
p_H	Price of houses (EUR million)	Free	0.22	Based on ECB
p_M	Price of green MBSs	Free	1	Selected from a reasonable range of values
POP	Population (Million people)	Free	348	Based on Eurostat
POP_R	Population of rentiers (Million people)	Model-constrained	139.2	Calculated from Eq. (113)
POP_W	Population of workers (Million people)	Model-constrained	208.8	Calculated from Eq. (112)
r	Rate of profit	Model-constrained	0.0471	Calculated from Eq. (67)
r_{HI}	Rate of return for houses	Model-constrained	0.0187	Calculated from Eq. (51)
r_{SH}	Rate of return on shares issued by MMFs	Model-constrained	0.0461	Calculated from Eq. (52)
$rent$	Rent rate (EUR million)	Model-constrained	0.0187	Calculated from Eq. (41)
$Rent$	Expenditure for rent (EUR trillion)	Free	0.9647	Based on ECB
$Repo$	Repo issued by IFs (EUR trillion)	Model-constrained	0.2452	Calculated from Eq. (157)
RP	Retained profits (EUR trillion)	Model-constrained	1.7701	Calculated from Eq. (65)
s	Proportion of green securitised loans	Free	0.09	Based on ECB
SEC	Total outstanding amount of government securities (EUR trillion)	Free	12.6933	The government securities in GDP is based on Eurostat
SEC_B	Government securities held by banks (EUR trillion)	Free	3.3703	The government securities held by banks in GDP is based on Eurostat and EBA
SEC_{CB}	Government securities held by central bank (EUR trillion)	Model-constrained	3.0171	Calculated from Eq. (177)
SEC_{CBred}	Government securities held by central bank (EUR trillion)	Model-constrained	3.0171	Calculated from Eq. (177)

SEC_{FVC}	Government securities held by MMFs (EUR trillion)	Free	1.3963	Selected from a reasonable range of values
SEC_{HI}	Government securities held by investor households (EUR trillion)	Model-constrained	4.275	Calculated from Eq. (176)
SEC_{IF}	Government securities held by IFs (EUR trillion)	Model-constrained	0.1269	Calculated from Eq. (156)
SEC_{MMF}	Government securities held by MMFs (EUR trillion)	Free	0.5077	Selected from a reasonable range of values
SH_{MMF}	MMF shares (EUR trillion)	Model-constrained	0.3672	Calculated from Eq. (166)
spr_H	Spread on housing loans	Model-constrained	0.01	Calculated from Eq. (134)
spr_{HC}	Spread on conv. housing loans	Model-constrained	0.01	Calculated from Eq. (132)
spr_{HG}	Spread on green housing loans	Model-constrained	0.01	Calculated from Eq. (131)
TAX	Total taxes (EUR trillion)	Model-constrained	2.9205	Calculated from Eq. (174)
TAX_C	Carbon tax revenues (EUR trillion)	Free	0.032	Based on ERCST (2025)
TAX_F	Taxes on firms' profits (EUR trillion)	Model-constrained	0.4315	Calculated from Eq. (172)
TAX_{HI}	Taxes on investor households' disposable income (EUR trillion)	Free	1.459	Selected from a reasonable range of values
TAX_{HW}	Taxes on worker households' disposable income (EUR trillion)	Model-constrained	0.998	Calculated from Eq. (170)
TP	Total profit of firms (EUR trillion)	Model-constrained	5.6443	Calculated from Eq. (64)
TP_G	Total gross profit of firms (EUR trillion)	Model-constrained	6.1078	Calculated from Eq. (62)
u	Capacity utilisation rate	Free	0.79	Based on Eurostat
V_{CB}	Wealth of central bank (EUR trillion)	Model-constrained	0	Calculated from Eq. (178)
V_{HI}	Wealth of investor households (EUR trillion)	Model-constrained	57.1389	Calculated from Eq. (46)
V_{HW}	Wealth of worker households (EUR trillion)	Model-constrained	2.433	Calculated from Eq. (5)
W	Wage income (EUR trillion)	Model-constrained	8.0245	Calculated from Eq. (63)
$WealthIndex$	Ratio of rentiers' to workers' wealth	Model-constrained	35.2268	Calculated from Eq. (110)
Y	Output (EUR trillion)	Free	14.59	Based on Eurostat
Y_{HI}	Disposable income of the investor households (EUR trillion)	Model-constrained	3.984	Calculated from Eq. (44)
Y_{HIG}	Gross disposable income of the investor households (EUR trillion)	Model-constrained	5.443	Calculated from Eq. (43)
Y_{HW}	Disposable income of the worker households (EUR trillion)	Model-constrained	5.7886	Calculated from Eq. (2)
Y_{HWG}	Gross disposable income of the worker households (EUR trillion)	Model-constrained	6.7867	Calculated from Eq. (1)
Y_{pot}	Potential output (EUR trillion)	Model-constrained	18.4684	Calculated from Eq. (69)
$yield_M$	Yield on green MBSs	Free	0.0384	Based on Marques-Pinto (2020)
β	Share of green investment in total investment	Model-constrained	0.3713	Calculated from Eq. (72)
β_H	Share of green houses to total houses	Free	0.34	Based on BPIE (2022)

Table A.5: Symbols and values for parameters and exogenous variables (baseline scenario)

Symbol	Description	Parameter category	Value	Source/remarks
c_{11}	Propensity to consume out of disposable income for worker households	Model-constrained	1.0356	Calculated from Eq. (3)
c_{12}	Propensity to consume out of wealth for worker households	Free	0.01	Selected from a reasonable range of values
c_{21}	Propensity to consume out of disposable income for investor households	Model-constrained	0.4749	Calculated from Eq. (45)
c_{22}	Propensity to consume out of wealth for investor households	Free	0.01	Selected from a reasonable range of values
c_{CIH}	Parameter linking the green to conventional housing stock with carbon housing intensity	Free	-1.4086	Selected from a reasonable range of values
c_{CIO}	Parameter linking the green to conventional capital stock with carbon other emissions intensity	Free	-1.1044	Selected from a reasonable range of values
CAR_{min}	Minimum capital adequacy ratio	Free	0.08	Based on the Basel III regulatory framework
CI_{H2035}	Carbon housing intensity target	Free	0.0033	Selected from a reasonable range of values
CI_{Hmax}	Maximum intensity rate for carbon intensity of houses	Free	0.005	Selected from a reasonable range of values
CI_{Hmin}	Minimum intensity rate for carbon intensity of houses	Free	0.0021	Selected from a reasonable range of values
CI_{O2050}	Carbon other emission intensity target	Free	0.0873	Selected from a reasonable range of values
CI_{Omax}	Maximum intensity rate for carbon intensity of other emissions	Free	0.1309	Selected from a reasonable range of values
CI_{Omin}	Minimum intensity rate for carbon intensity of other emissions	Free	0.0546	Selected from a reasonable range of values
$CR_{initial}$	Initial degree of credit rationing	Free	0.2	Selected from a reasonable range of values
CR_{max}	Maximum degree of credit rationing	Free	0.5	Selected from a reasonable range of values
def_0	Parameter in the default rate function	Free	14	Selected from a reasonable range of values
def_1	Parameter in the default rate function	Free	13.3929	Selected from a reasonable range of values
def_2	Parameter in the default rate function	Free	13.3929	Selected from a reasonable range of values
def_{max}	Maximum default rate of housing loans	Free	0.3	Selected from a reasonable range of values
fee	Fee rate	Free	0.0057	Based on Karimov et al (2025)
gov_C	Share of government expenditure in output	Model-constrained	0.2142	Calculated from Eq. (169)
h_1	Banks' reserve ratio	Model-constrained	0.3933	Calculated from Eq. (123)
h_{10}	Parameter in the worker households' desired demand for houses	Model-constrained	0.072	Calculated from Eq. (16)
h_{13}	Parameter in the worker households' desired demand for houses (growth rate of workers population)	Free	0.01	Selected from a reasonable range of values
h_{14}	Parameter in the worker households' desired demand for houses (rents)	Free	0.01	Selected from a reasonable range of values
h_2	Banks' government securities-to-deposits ratio	Model-constrained	0.154	Calculated from Eq. (124)
h_{20}	Parameter in the housing investment function	Model-constrained	0.0107	Calculated from Eq. (80)
h_3	Parameter in housing prices	Free	0.02	Selected from a reasonable range of values
h_{33}	Parameter in the housing price equation	Model-constrained	0	Calculated from Eq. (90)
h_{IF}	Share of government securities owned by IFs	Free	0.01	Selected from a reasonable range of values

HG_{HC2034}	Housing intensity target	Free	0.52	Selected from a reasonable range of values
int_C	Interest rate on conventional loans	Free	0.05	Based on ECB
int_D	Interest rate on deposits	Free	0.02	Based on ECB
int_G	Interest rate on green loans	Free	0.05	Based on ECB
int_{max}	Maximum interest rate on advances	Free	0.03	There is no policy in the first year
int_{min}	Minimum interest rate on advances	Free	0.03	There is no policy in the first year
int_R	Interest rate on repos	Free	0.035	Based on ICMA (2022)
int_{ref}	Reference interest rate on advances	Free	0.03	Selected from a reasonable range of values
int_S	Interest rate on government securities	Free	0.028	Based on ECB
int_{SUB}	Green loan subsidy rate	Free	0.0016	Based on OECD (2024)
KG_{KC2034}	Capital stock intensity target	Free	0.59	Selected from a reasonable range of values
p_{Constr}	Price of constructed houses (EUR trillion per million houses)	Model-constrained	0.0959	Calculated from Eq. (84)
p_{Mbar}	Par value price of green MBSs (EUR)	Free	1	Selected from a reasonable range of values
p_{Refurb}	Price of refurbished houses (EUR trillion per million houses)	Model-constrained	0.0172	Calculated from Eq. (89)
$prop_D$	Proportion of workers' deposits to income	Model-constrained	0.3856	Calculated from Eq. (4)
$prop_{HIRent}$	Proportion of rented houses, percent of total houses	Free	0.28	Based on Based on ECB
$prop_{IOwnOccup}$	Proportion of owned houses rentiers wish to rent	Free	0.012	Selected from a reasonable range of values
$prop_{IRented}$	Proportion of rented houses rentiers wish to sell	Free	0.001	Selected from a reasonable range of values
$prop_{NewRented}$	Proportion of new rented houses	Model-constrained	0.0553	Calculated from Eq. (35)
$prop_{RentedSold}$	Proportion of rented houses that were sold	Model-constrained	7e-04	Calculated from Eq. (26)
$prop_{Vacancy}$	Vacancy rate, percent of total houses	Free	0.11	Based on Based on ECB
$prop_W$	Proportion of new own-occupied houses by workers to total new houses	Model-constrained	0.0615	Calculated from Eq. (23)
$prop_{WExisting}$	Proportion of owned houses rentiers wish to sell	Free	0.01	Selected from a reasonable range of values
$prop_{Workers}$	Share of workers	Free	0.6	Selected from a reasonable range of values
r_0	Parameter in the credit rationing of housing loans	Free	1.5	Selected from a reasonable range of values
r_1	Parameter in the function of the credit rationing on housing loans	Model-constrained	-1.4361	Calculated from Eq. (128)
r_2	Parameter in the credit rationing of housing loans	Free	8.5397	Selected from a reasonable range of values
r_3	Parameter in the credit rationing of housing loans	Free	83.3333	Selected from a reasonable range of values
$rent_0$	Parameter linked to the rent equation	Model-constrained	0	Calculated from Eq. (42)
$rent_1$	Parameter linked to the rent equation	Free	0.01	Selected from a reasonable range of values
rep_L	Repayment of loans	Free	0.1	Selected from a reasonable range of values
s_0	Parameter linked to green securitised loans	Model-constrained	0.09	Calculated from Eq. (120)
s_1	Parameter in the share of green securitised mortgages	Free	1	Selected from a reasonable range of values
s_B	Banks' retention rate	Model-constrained	0.715	Calculated from Eq. (116)
s_F	Firms' retention rate	Model-constrained	0.3199	Calculated from Eq. (78), (186), (79), (70) and (65)
s_{FVC}	FVCs retention rate	Model-constrained	1.0003	Calculated from Eq. (143)
s_{IF}	IFs retention rate	Model-constrained	0.6291	Calculated from Eq. (152)
s_{MMF}	MMFs retention rate	Model-constrained	0.3493	Calculated from Eq. (162)

s_W	Wage share	Free	0.55	Based on Penn World Table 10.0 (see Feenstra, 2015)
$size$	Average household size	Free	2.3	Based on Eurostat
spr_{H0}	Parameter in the spread on housing loans	Model-constrained	0.0069	Calculated from Eq. (133)
spr_{H2}	Parameter in the lending spread on housing loans (debt service ratio)	Free	0.0232	Selected from a reasonable range of values
v	Capital productivity	Model-constrained	80	Calculated from Eq. (68) and (69)
w_H	Risk weight on high-powered money	Free	0	Based on BCBS (2023)
w_L	Risk weight on loans	Free	1	Based on BCBS (2023)
w_R	Risk weight on repos	Free	0.1	Based on BCBS (2023)
w_S	Risk weight on government securities	Free	0	Based on BCBS (2023)
$yield_{MT}$	Target yield on green MBSs	Free	0.0384	Selected from a reasonable range of values
α_{00}	Parameter in investment function	Free	0.04	Selected from a reasonable range of values
α_{01}	Parameter in the investment function	Model-constrained	1.0539	Calculated from Eq. (70)
α_1	Parameter in the investment function (related to the sensitivity to the capacity utilisation)	Free	0.69	Selected from a reasonable range of values
α_2	Parameter in the investment function (related to the sensitivity to the profit rate)	Free	10.8	Selected from a reasonable range of values
β_0	Parameter for the green investment share	Model-constrained	0.3713	Calculated from Eq. (71)
β_1	Parameter for the green investment share to the interest rate differential	Free	1	Selected from a reasonable range of values
β_{H0}	Parameter in share of green houses	Model-constrained	0.3384	Calculated from Eq. (17)
ϵ_0	Parameter in the haircut	Model-constrained	0.2451	Calculated from Eq. (154)
ϵ_1	Parameter in haircuts	Free	1	Selected from a reasonable range of values
γ_{10}	Parameter of MMFs portfolio choice	Model-constrained	0.8334	Calculated from Eq. (163)
γ_{11}	Parameter of MMFs portfolio choice	Free	0.01	Selected from a reasonable range of values
γ_{12}	Parameter of MMFs portfolio choice	Free	-0.01	Selected from a reasonable range of values
γ_{20}	Parameter of MMFs portfolio choice	Model-constrained	1.4106	Calculated from Eq. (164)
γ_{21}	Parameter of MMFs portfolio choice	Free	-0.01	Calculated from the constraint
γ_{22}	Parameter of MMFs portfolio choice	Free	0.01	Selected from a reasonable range of values
κ_{CIH}	Parameter linking the green to conventional housing stock with carbon housing intensity	Free	52.4652	Selected from a reasonable range of values
κ_{CIO}	Parameter linking the green to conventional capital stock with carbon other emissions intensity	Free	-513.9948	Selected from a reasonable range of values
λ_{10}	Parameter of investor households' portfolio choice	Model-constrained	0.077	Calculated from Eq. (47)
λ_{11}	Parameter of investor households' portfolio choice	Free	0.03	Calculated from the constraint
λ_{12}	Parameter of investor households' portfolio choice	Free	-0.01	Selected from a reasonable range of values
λ_{13}	Parameter of investor households' portfolio choice	Free	-0.01	Selected from a reasonable range of values
λ_{14}	Parameter of households' portfolio choice	Free	-0.01	Selected from a reasonable range of values
λ_{15}	Parameter of households' portfolio choice	Free	-0.01	Selected from a reasonable range of values
λ_{20}	Parameter of investor households' portfolio choice	Model-constrained	0.2625	Calculated from Eq. (48)
λ_{21}	Parameter of investor households' portfolio choice	Free	-0.01	Calculated from the constraint

λ_{22}	Parameter of investor households' portfolio choice	Free	0.03	Calculated from the constraint
λ_{23}	Parameter of investor households' portfolio choice	Free	-0.01	Selected from a reasonable range of values
λ_{24}	Parameter of investor households' portfolio choice	Free	-0.01	Selected from a reasonable range of values
λ_{25}	Parameter of investor households' portfolio choice	Free	-0.01	Selected from a reasonable range of values
λ_{30}	Parameter of investor households' portfolio choice	Model-constrained	0.0065	Calculated from Eq. (49)
λ_{31}	Parameter of investor households' portfolio choice	Free	-0.01	Calculated from the constraint
λ_{32}	Parameter of investor households' portfolio choice	Free	-0.01	Calculated from the constraint
λ_{33}	Parameter of investor households' portfolio choice	Free	0.03	Calculated from the constraint
λ_{34}	Parameter of investor households' portfolio choice	Free	-0.01	Selected from a reasonable range of values
λ_{35}	Parameter of investor households' portfolio choice	Free	-0.01	Selected from a reasonable range of values
λ_{40}	Parameter of investor households' portfolio choice	Model-constrained	0.3498	Calculated from Eq. (189)
λ_{41}	Parameter of investor households' portfolio choice	Free	-0.01	Calculated from the constraint
λ_{42}	Parameter of households' portfolio choice	Free	-0.01	Calculated from the constraint
λ_{43}	Parameter of investor households' portfolio choice	Free	-0.01	Calculated from the constraint
λ_{44}	Parameter of households' portfolio choice	Free	0.03	Calculated from the constraint
λ_{45}	Parameter of households' portfolio choice	Free	0.03	Calculated from the constraint
τ_C	Carbon tax (EUR trillion/GtCO2)	Model-constrained	0.0205	Calculated from Eq. (173)
τ_F	Firms' tax rate	Model-constrained	0.0721	Calculated from Eq. (168) and (167)
τ_{HI}	Investor households' tax rate	Model-constrained	0.2734	Calculated from Eq. (171)
τ_{HW}	Worker households tax rate	Free	0.15	Selected from a reasonable range of values

References

Acharya, V.V., Schnabl, P., Suarez, G., 2013. Securitization without risk transfer. Journal of Financial Economics 107, 515–536.

Adrian, T., Shin, H.S., 2010. Liquidity and leverage. Journal of Financial Intermediation 19, 418–437.

Albanesi, S., DeGiorgi, G., Nosal, J., 2022. Credit growth and the financial crisis: A new narrative. Journal of Monetary Economics 132, 118–139.

BCBS, 2025. Calculation of RWA for credit risk, CRE20: Standardised approach — individual exposures. Bank for International Settlements CRE20. URL: https://www.bis.org/basel_framework/.

BIS, 2023. Bank for International Settlements database for debt service ratios for the private non-financial sector. Data documentation. Bank for International Settlements. URL: https://www.bis.org/statistics/dsr/dsr_doc.pdf.

Blecker, R.A., 2002. Distribution, demand and growth in neo-Kaleckian macro-models, in: Setterfield, M. (Ed.), The Economics of Demand-Led Growth. Edward Elgar, Cheltenham, UK and New York, US, pp. 129–152.

BPIE, 2022. EU Buildings Climate Tracker: Methodology and introduction of building decarbonisation indicators and their results. Technical Report. Buildings Performance Institute Europe. Available at: https://www.bpie.eu/publication/eu-buildings-tracker-methodology-and-results-for-building-decarbonisation-indicators/.

Byrialsen, M.R., Valdecantos, S., Raza, H., 2024a. Wage-led or profit-led: is it the right question to examine the relationship between income inequality and economic growth? insights from an empirical stock-flow consistent model for denmark. Cambridge Journal of Economics 48, 303–328.

Byrialsen, M.R., Valdecantos, S., Raza, H., Laurentjoye, T., 2024b. Functional income distribution, effective demand and wealth in denmark–insights from an empirical stock-flow consistent model. Journal of Post Keynesian Economics 47, 766–794.

Caiani, A., Godin, A., Caverzasi, E., Gallegati, M., Kinsella, S., Stiglitz, J.E., 2016. Agent based-stock flow consistent macroeconomics: Towards a benchmark model. Journal of Economic Dynamics & Control 69, 375–408.

Dafermos, Y., Nikolaidi, M., 2022. Assessing climate policies: an ecological stock–flow consistent perspective. European Journal of Economics and Economic Policies: Intervention 19, 338–356.

Deku, S.Y., Kara, A., Semeyutin, A., 2021. The predictive strength of mbs yield spreads during asset bubbles. Review of Quantitative Finance and Accounting 56, 111–142.

Dunz, N., Naqvi, A., Monasterolo, I., 2021. Climate sentiments, transition risk, and financial stability in a stock-flow consistent model. Journal of Financial Stability 54, 100872.

Eatwell, J., Mouakil, T., Taylor, L., 2008. Liquidity, leverage and the impact of sub-prime turbulence. Centre for Financial Analysis and Policy, Judge Business School, University of Cambridge , 1–25.

ECB, 2025. Investment funds' financial leverage – material and systemic? Macroprudential Bulletin URL: https://www.ecb.europa.eu/press/financial-stability-publications/macroprudential-bulletin/focus/2025/html/ecb.mpbu202501_focus02.en.html.

EOS, 2024. Annual Report of the European Sawmill Industry 2023–2024. Technical Report. European Organisation of the Sawmill Industry (EOS). Brussels. URL: https://eos-oes.eu/wp-content/uploads/2024/06/eos-annual-report-2023-2024.pdf.

ERCST, 2025. 2025 State of the EU ETS Report. Annual report. European Roundtable on Climate Change and Sustainable Transition (ERCST). Brussels. URL: https://ercst.org/wp-content/uploads/2025/05/20250520-2025-State-of-the-EU-ETS-Report-Final.pdf. authors include Andrei Marcu, Emma Coker, Florian Bourcier, Jean-Yves Caneill, Stefan Schleicher, Juan Fernando López Hernández, Nigel Caruana, Peter Chawah, Rosy Finlayson; partners: BloombergNEF, Wegener Center (Uni Graz), Compass Lexecon.

European Commission, 2025. Dg climate action ets2: Buildings, road transport and additional sectors. https://climate.ec.europa.eu/eu-action/carbon-markets/ets2-buildings-road-transport-and-additional-sectors_en.

Feenstra, R.C., Inklaar, R., Timmer, M.P., 2015. The next generation of the Penn World table. American Economic Review 105, 3150–3182. doi:10.1257/aer.20130954.

Godley, W., 1999. Money and credit in a Keynesian model of income determination. Cambridge Journal of Economics 23, 393–411.

Godley, W., Lavoie, M., 2012. Monetary Economics: An Integrated Approach to Credit, Money, Income, Production and Wealth. Second ed., Palgrave Macmillan, Basingston, UK and New York, US.

Grovenstein, R.A., Harding, J.P., Sirmans, C., Thebpanya, S., Turnbull, G.K., 2005. Commercial mortgage underwriting: How well do lenders manage the risks? Journal of Housing Economics 14, 355–383.

ICMA, 2024. The European repo market at 2023 year-end. ICMA European Repo & Collateral Council (ERCC) briefing note. International Capital Market Association. URL: https://www.icmagroup.org/assets/documents/Regulatory/Repo/ICMA-ERCC-Briefing-note-The-European-repo-market-at-2023-year-end-January-2024-290124.pdf.

ICMA, 2025. European repo and collateral council (ercc) frequently asked questions on repo — 21. what is a haircut? URL: https://www.icmagroup.org/market-practice-and-regulatory-policy/repo-and-collateral-markets/icma-ercc-publications/frequently-asked-questions-on-repo/21-what-is-a-haircut/.

Jackson, T., Victor, P.A., 2019. Low-grow SFC: a stock-flow-consistent model ecological macroeconomic model for Canada. CUSP Working Paper 16.

Jourdan, S., van Tilburg, R., Kramer, B., Simić, A., Bronstering, G., 2024. A green interest rate for the eurozone: Evaluating the design choices. Available at SSRN 5015926 .

Kaldor, N., 1940. A model of the trade cycle. The Economic Journal 50, 78–92.

Karimov, N., Kara, A., Downing, G., 2025. Investment bank reputation and issuance fees: Evidence from asset-backed securities. Review of Quantitative Finance and Accounting 65, 599–618.

van't Klooster, J., van Tilburg, R., 2020. Targeting a sustainable recovery with Green TLTROs. Positive Money publications. URL: http://www.positivemoney.eu/wp-content/uploads/2020/09/Green-TLTROs.pdf.

Krebel, L., van Lerven, F., 2022. A green term funding scheme for a cooler future. Green credit guidance. New Economics Foundation.

Marques, M.O., Pinto, J.M., 2020. A comparative analysis of ex ante credit spreads: Structured finance versus straight debt finance. Journal of Corporate Finance 62, 101580.

NGFS, 2025. NGFS short-term climate scenarios. Technical Report. Network for Greening the Financial System. URL: https://www.ngfs.net/en/publications-and-statistics/publications/ngfs-short-term-climate-scenarios-central-banks-and-supervisors.

Nikolaidi, M., 2015. Securitisation, wage stagnation and financial fragility: A stock-flow consistent perspective. Working Paper GPERC27.

OECD, 2024. Indicator PH7.1. Measures to Finance Housing Improvements and Regeneration. OECD Affordable Housing Database.

Santos, C.H.d., Zezza, G., 2004. A Post-Keynesian stock-flow consistent macroeconomic growth model: Preliminary results. Technical Report. Levy Economics Institute.

Schroth, E., Suarez, G.A., Taylor, L.A., 2014. Dynamic debt runs and financial fragility: Evidence from the 2007 abcp crisis. Journal of Financial Economics 112, 164–189.

Walther, U., 2024. European securitisation market – ready for a comeback? EU Monitor. Deutsche Bank Research. URL: https://www.dbresearch.com/PROD/RPS_EN-PROD/PROD0000000000546960/European_securitisation_market_%E2%80%93_ready_for_.pdf.

Zezza, G., 2008. Us growth, the housing market, and the distribution of income. Journal of Post Keynesian Economics 30, 375–401.