# Eurozone Sustainable Finance Model

**model documentation Vensim code** version : March 2026

The Eurozone Sustainable Finance Model (ESFM) simulates the dynamic interactions in and between the economic and financial system in the Eurozone. Following the stock-flow consistent modelling approach, the model accounts for the non-equilibrium nature of the economy and the money stocks and flows in it. The model and its application are described in:

Egmond, N.D. van and B.J.M. de Vries (2024)
**Reforming the Eurozone financial system: A system-dynamics approach**.
*International Review of Financial Analysis* 93 (2024). https://doi.org/10.1016/j.irfa.2024.103192.
Literature references in the text below refer to this publication.

The ESFM-model is programmed in VENSIM. In order to run the model and/or change / extend it, the general VENSIM software (PLE version) can be (free) downloaded from: https://vensim.com/free-downloads/. The ESFM software then can be opened and run.

## 1 Model structure

The structure of the ESFM is given in Figure 1a.
The *economic system* is modelled as a closed economy in which goods and services are produced using capital and labour as inputs. There are three economic sectors; a Manufacturing, a Service and a Government sector. The economic development in the Manufacturing and in the Service sector is modelled via (CES-CD) production functions, which account for the gradual shift from labour to capital as contributing production factors (left hand side Figure 1a). Capital and labour inputs are based on marginal profitability considerations. Prices of manufactured goods and service, labour (wages) and assets are simulated by supply-demand equilibrating mechanisms with delay. The (natural) interest rate is modelled as a function of supply and demand of money.

The *financial system* is modelled as an aggregate bank and thus has the structure of a bank balance sheet, with assets (left) and liabilities (right hand side). The deposit holders are private (production) firms, government, a (central) bank and four groups of consumers:

- Minimum (M-) consumers with a low income that is entirely spent on consumption;
- Indebted (D-) consumers who have obtained loans / mortgages from the bank(s) to buy real assets, in particular houses;
- LAB-consumers with higher income / wealth, not only from Labour but also from increasing Asset prices and having government Bonds;
- LABD- consumers who, apart from Labour, have additional income / wealth from increasing Asset prices, bonds and from the profits (Dividends) of (capital) shares of private firms. The deposits of the latter two higher income consumer groups are considered to represent the 'financial markets'. As a consequence, 'liquidity' is defined as the amount of money on the LAB- and LABD-deposits.

*Loans* can be given to consumers, firms and the government. In case of bank loans, these loans enter as debts on the asset side and as deposits on the liability side. In the process, money is created as debt by (simultaneous) elongation of both the asset and the liability side of the bank balance sheet. The *government* redistributes wealth by taxation and social payments and invests in societal functions.

The model covers the period 1950-2060. Economic activity is driven by three exogenous time-series: population (growth) and with it the available labour force, the (growth of) labour and capital productivity and the (change in) ratio between consumption of manufacturing and service sector output. All other dynamics stem from the mechanisms discussed below. The model is tuned to the available empirical data for the period 1950-2020 and used for exploration of the period 2020-2050 (Trading Economics, 2023).

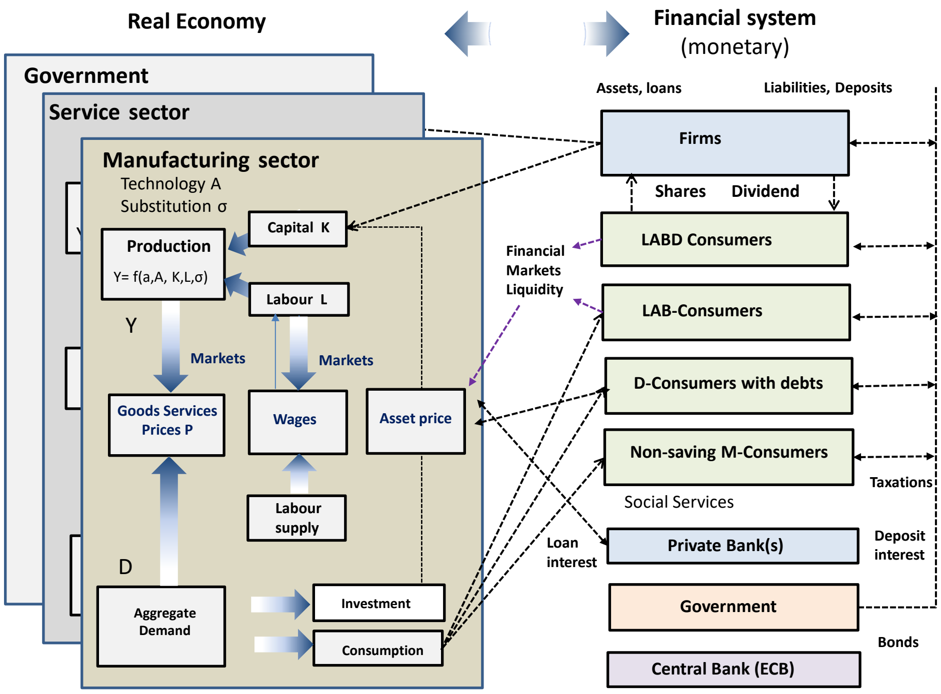


*Figure 1a Overall scheme of the ESF-model*

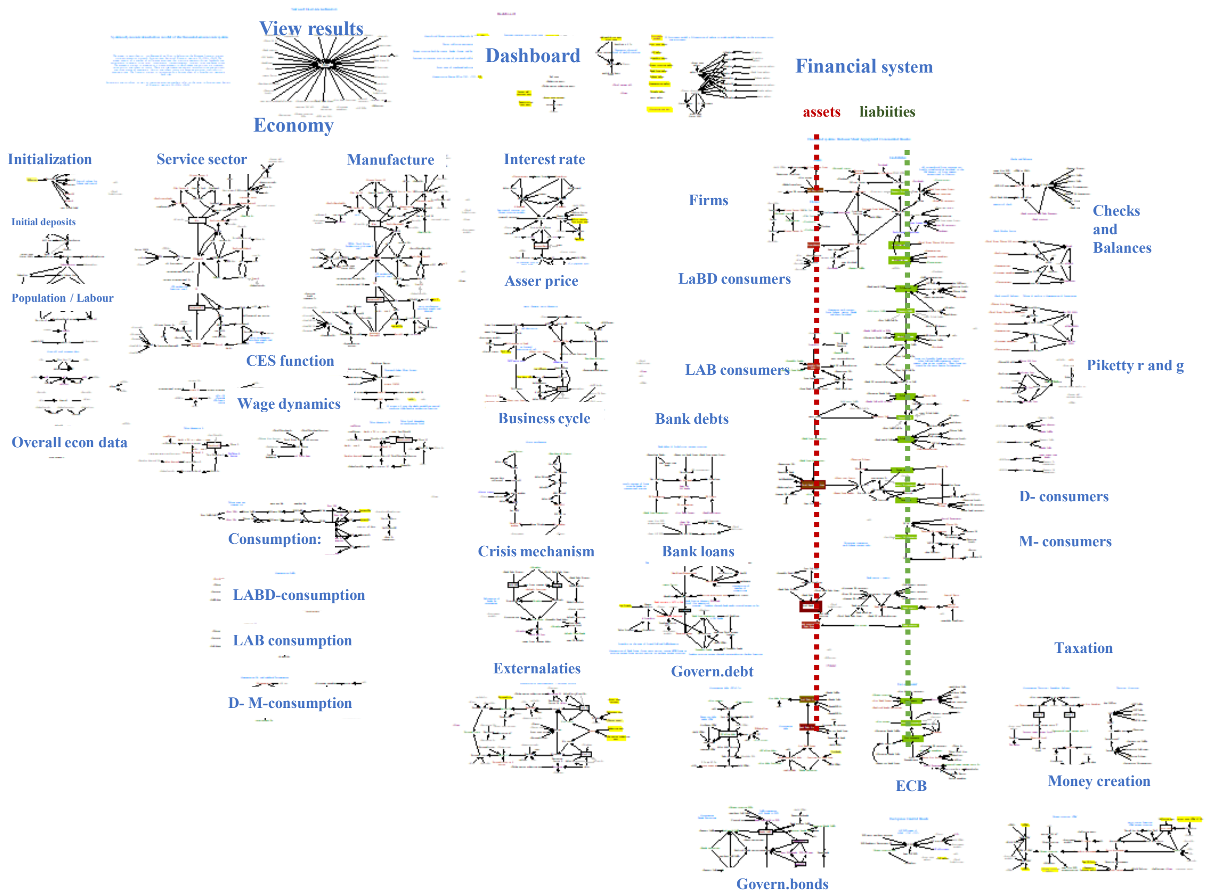


*Figure 1.1b Vensim-sheet: representation of ESF-model (as shown in Figure 1a)*

The overall lay-out of the Vensim-code is given in Figure 1b and as much as possible corresponding to the scheme of Figure 1a. De model is built as a network of linked modules with specific functions. The green dotted vertical line indicates the Liability side of the overall (average) bank balance sheet. The deposits themselves are represented by green boxes. The dark-red dotted line indicates the outstanding debts on the Asset side of the balance sheet. The individual debts are represented by dark-red / brown boxes.

In Figure 1.2 the standard control functions of the Vensim sheet are shown. The model is run by clicking the green button, indicated by the green arrow (Figure 1.2a). By clicking the '*f(x)* Equation' button (step 1) and subsequently (step 2) the icon of the variable under concern (in this example total production 'pY'), a window opens, showing the computational content of pY which might be an equation or the value /number of a specific parameter. In the example the pY window shows that pY is computed as the sum pYM + pYS + pYGov (indicated by the purple colour).

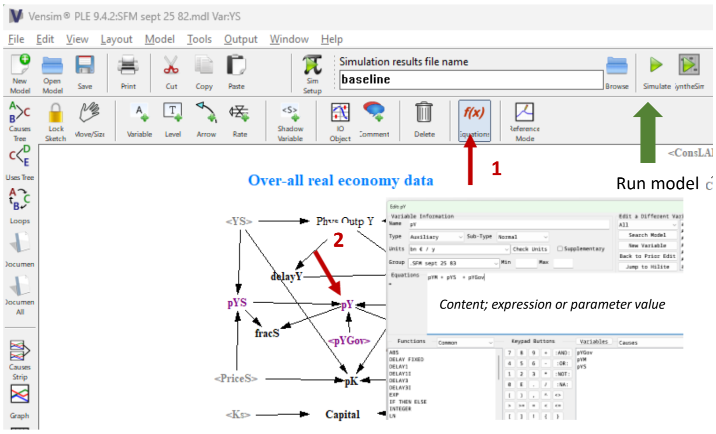


*Figure 1.2a*

By clicking the 'Move/size' button (step 1), and pY (step 2) and finally clicking on the '**Graph'** button on the left (step 3), the window shows the dynamical behaviour of the variable pY over the modelling period; Figure 1.2b**.**
By holding the Shift key (keyboard), several variables can be displayed in a single graph.

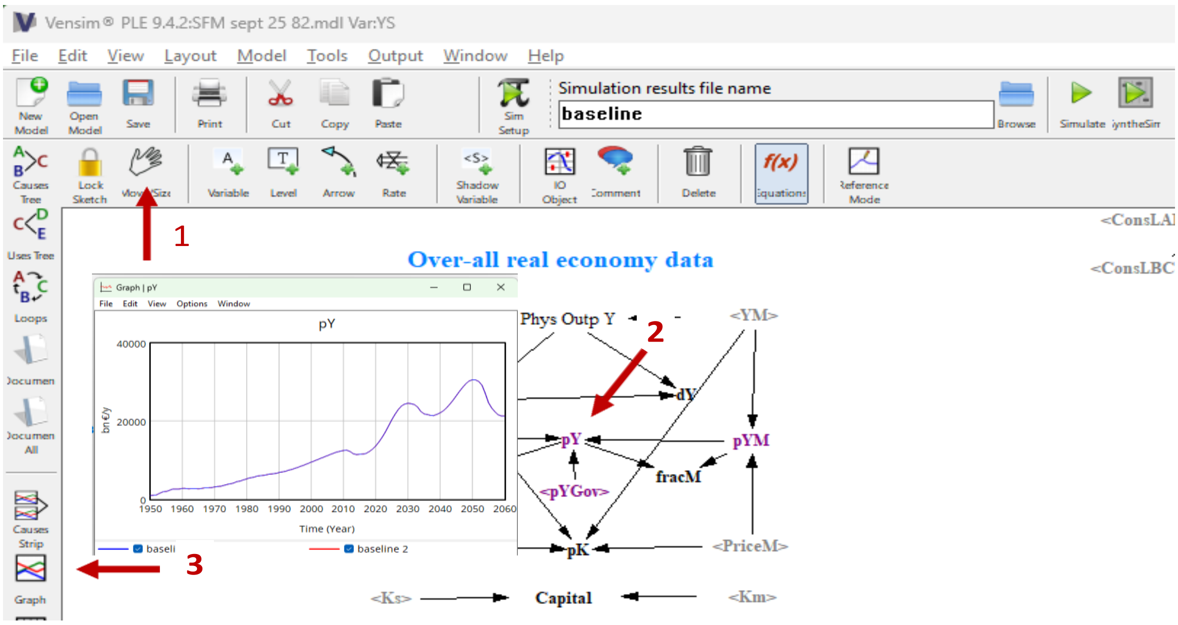


*Figure 1.2b*

In case rather than the button ‘graph’, the button **Causal strip** is clicked in step 3 (Figure 1.2c), the dynamical behaviour pY will be shown in combination with the variables which directly cause pY. In the upper left part of the model sheet, the variable **View** is displayed as the sum of many other (well chosen) variables. By clicking **View** all these variables are displayed at the same time, giving a very effective diagnosis of the overall functioning of the system. ((The resulting value of View itself is meaningless. Alternatively a choice of variables can be plotted in a single graph, by holding the Shift-key.

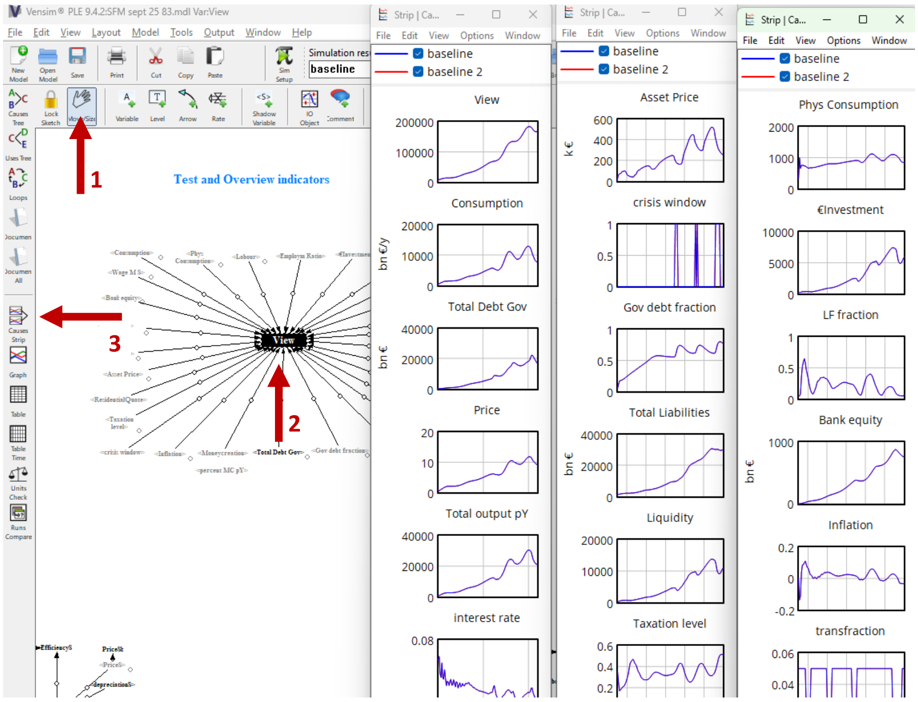


*Figure 1.2c*

By clicking ‘*Table Time’* in the lower part of the left icons-column of the model sheet (see Figure 1.2c), the data for (several subsequent) runs will be displayed as a Table. By clicking *‘Save’* under the tab ‘*File*’, the table can be stored to a Text-file. This file can be converted and copied to an Exel-file, from which graphs can be made (after changing decimal dots to comma’s).

Computational variables can by found by opening the *Edit* menu in the Vensim toolbar, extreme upper left in the Vensim sheet, and clicking *Find*. After filling in the variable name, its position is indicated in the sheet.

In the model sheet, the many different variables are given colours with the following meaning:
**Green** icons are variables which connect the respective modules (parts of the model; input-output)
**Purple** icons represent variables which are relevant in the computation or delineate substructures within more complex modules.
**Module** names and explaining comments in the model sheet are indicated as blue.
**Icons** which are highlighted by a yellow background are ‘buttons’ which activate (=1) or deactivate (=0) specific functions, for example representing specific monetary policies. The most relevant buttons are concentrated in the Dashboard at the top of the model sheet (Figure 1.2d). The icons also might represent inputs which can be changed in model-experiments. In case the variable icon is for example about a year, the year has to be set by opening the icon’s window (Figure 1.2a) and changing the year. Other variables / parameters are about magnitudes of interventions etc.

Icons within a **frame** ▭ represent ‘levels’; these levels might have computational functions (integration) or represent financial ‘stocks’, for example the deposits on the bank balance sheets, the levels of which continuously change as the results of inputs and outputs.

In the current model documentation, variables which directly refer to, and appear in the model sheet (and detailed parts thereof in respective figures) are indicated in **blue**

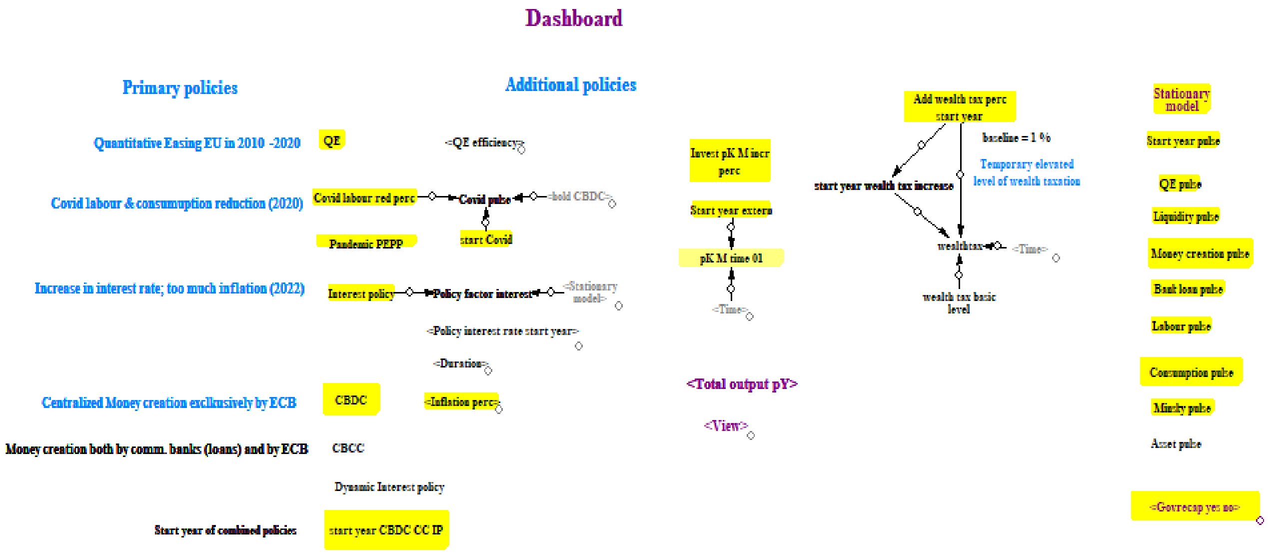


*Figure 1.2d. Dashboard for setting the most important model parameters.*

All options / conditions are activated by setting the respective parameter to 1; deactivating by resetting to 0. The following options for running the model are available:

| | |
|---|---|
| QE | Quantitative Easing is applied by the ECB in the historical period 2012-2022, which is reconstructed by QE=1. In case QE=0, the development over time is hypothetically reconstructed without this ECB-policy intervention. QE efficiency is the fraction of the total QE program (Asset Purchase Program and Pandemic Emergency Purchase Program) which has effectively reached the real economy. |
| Covid PEProgram 2020 | Covid Labour reduction percentage is the percentage of reduction (30 %) in the year 2020 (start Covid) of total factor productivity A (in eqn 1 below) and consumption of LAB- and LABD-consumers. |
| Policy interest rate | allows the effectuation of a temporary higher (policy) interest rate over a period with a certain Duration and a Policy interest rate start year. The level of the increase can be chosen in Policy factor interest. |
| Externalities; capital costs | Given the realistic, gradual shift from labour to capital in the economic (CES) production function, the model describes infinite economic growth. However, more realistic mitigation conditions can be modelled as they are now visible in environmental and resource policies. These conditions are simulated by increasing the price pK of capital for investments in the manufacture sector (scarce resources, etc.). |
| CBDC | Starting from a start year (CBDC CBCC IP), money is no longer created by commercial banks in the process of the creation of Bank Loans, but |

| | |
|---|---|
| | exclusively part of the mandate of the ECB. The money creation is dedicated to the ECB-objective of realizing a chosen inflation target (2%). |
| CBCC | Starting from the same start year, while commercial banks continue usual money creation, ECB is allowed to create currency as well, again directed to the chosen inflation target. (CBDC and CBCC options are mutually exclusive) |
| Dynamic Interest Policy | can be chosen in any combination with CBDC and CBCC. In this case the ECB is assumed to increase the natural, dynamic interest rate in times when inflation is too high. This policy is complementary to the money creation. In case of too low inflation more money is created, in case of too high inflation, the interest rate is increased. Both (dynamic) policies are directed to the primary objective of maintaining the target inflation. |
| Wealth taxation | Taxation on wealth as given by the respective consumer bank deposits is set to 1%. In case Wealth tax 2 perc is set to 1, this taxation level is increased to 3 % starting from 2020 over the full remaining period. (this can be changed) |
| Stationary model | By setting Stationary model =1, the model attains the stationary mode (no growth etc) from 1975 onwards. In this mode isolated temporary pulses can be given for the model parameters / conditions: QE , Liquidity, Money creation, Bank loan, Labour, Consumption, Minsky moment and Asset price. The important effects of an increase in interest rate can be studied by application of the above mentioned policy interest rate mechanism (and Stationary model =1). |

## 2 Dynamic processes

### 2.1 Production

Goods and services are produced using investments (€/yr) and labour (fte/yr) as inputs for the Manufacturing, Service and Government sector. Total output (or production) Y consists of (non-durable) consumption goods and services and (durable) investment goods such as machinery, equipment, buildings and infrastructure. The output of the manufacturing and service sectors, $Y_M$ and $Y_S$ respectively, are simulated by means of a constant elasticity of substitution (CES) production function (Jackson and Victor 2016,p.206-219)[1]

$$Y(K,L,\sigma) = \left( a\,K^{\left(\frac{\sigma-1}{\sigma}\right)} + (1-a)(A\,L)^{\left(\frac{\sigma-1}{\sigma}\right)} \right)^{\left(\frac{\sigma}{\sigma-1}\right)} \qquad [G/yr]^{2} \qquad (1)$$

with 'a' the parameter which distributes production (initially) to capital K and labour L and A representing technology- and organization-driven increase in labour productivity. The computational scheme is given in Figure 3. The factor A (total factor productivity TFP) is assumed to increase linearly over time. A CES production function is chosen to represent an ongoing substitution of labour by capital. This is achieved by increasing the values for σ (sigma; both the manufacturing and service sector) over time. In the current model application, this results in the increase of the overall capital-fraction from 0.25 (1950) to 0.40 (2050). For numerical / computational reasons, the physical production Y is computed in two steps; CESbase and Y (Y = CESbase ^ $\left(\frac{\sigma}{\sigma-1}\right)$ )

1 For elasticity of substitution σ = 1, the CES production function is equivalent to the simpler Cobb-Douglas (CD) production function: $Y = K^{\alpha} \,.\, (A\;\; L)^{1-\alpha}$. The exponent α represents the fraction of output that falls on the factor capital.

2 Physical stocks and flows are indicated with the letter G; monetary stocks and flows in Euros (€).; and labour inputs in fte's.

The *physical* economy of production is linked to the *monetary* economy of income for workers and investors through the following identity:

$$pY = I + C = wL + \pi_{gross} \qquad [€/yr] \qquad (2)$$

with pY the price level(s) p (price) times the physical production Y, being equal to total monetary production or GDP, I is the total investment flow (€Gross Invest), C the level of consumption, w the wage level, wL the rewards for labour and $\pi_{gross}$ the gross profits. The net profit is found as total production pY minus the costs which have to be paid for labour, capital and environment:

$$\pi_{net} = \pi_{gross} - (\delta + \rho + \varepsilon)p_k K = pY - wL - (\delta + \rho + \varepsilon)p_k K \qquad (3)$$

Herein, ρ (ro) is the interest rate at which firms can lend money (see below), δ (delta) the depreciation rate and ε an optional fraction that represents the extra capital costs for coping with external costs. The term (ρ + δ + ε) $p_K$ K is the flow of interest and dividend paid to capital owners, reinvested profits and external costs. $p_K$ is the price of capital (for investments).

Investors increase the capital stock with an amount dK until the marginal profitability of an additional unit of capital becomes zero. The size of dK will, besides depreciation, be some function of the (expected) profit $\pi_K$ of investing additional capital. The additional costs of an increase dK is $p_K$ (ρ dK + δ dK + $\varepsilon\, dK$), with $p_K$ the price of one unit of capital (Mankiw 2007) and with ρ the natural interest rate at which the firm can get a loan or some other form of capital on the capital market. The marginal profit rate per additional unit of capital (ProfitRateCap) can now be expressed as:

$$\pi_K = \frac{p\, dY - p_K\,(\rho+\delta+\varepsilon)\, dK}{p_K(\rho+\delta+\varepsilon)dK} = \frac{p}{p_K}\frac{\partial Y}{\partial K}\frac{1}{(\rho+\delta+\varepsilon)} - 1 \qquad [-] \qquad (4)$$

In case the price of capital $p_K$ (PriceMk) follows the general price level ($p/p_K \sim 1$), investments will only be made if the marginal capital productivity $\frac{\partial Y}{\partial K}$ exceeds (ρ+δ+ε) (eqn. 4). Again assuming that the relationship is linear, the dynamic equation for capital K, and thus (intended) net investment I (Net Invest), becomes in physical units:

$$I_{net} = \frac{dK}{dt} = \frac{\pi_K}{\tau_K}K = \frac{1}{\tau_K}\left(\frac{\partial Y}{\partial K}\frac{1}{(\rho+\delta+\varepsilon)} - 1\right)K \qquad [G/yr] \qquad (5)$$

This equation states that firms will invest in new production opportunities as long as the (expected) profits are positive, that is, dY > (ρ+δ +ε) dK or αY > (ρ+δ +ε) K. The time period over which entrepreneurs respond to the (change in) return on investment is given by the response parameter $\tau_K$ (tau invest)

Capital investments cause an increase in the labour force dL. The cost of this additional labour equals w dL, with w the wage level in monetary units per year. The marginal profit rate per additional labour unit (ProfitRateLabour) expressed in wage units can thus be written as:

$$\pi_L = \frac{p.dY - w\,dL}{w\;dL} = \frac{p}{w}\frac{\partial Y}{\partial L} - 1 \qquad [-] \qquad (6)$$

The additional labour input results in decreasing marginal labour productivity $\frac{\partial Y}{\partial L}$ and the marginal profit rate tends towards zero. In first instance the simplifying assumption is made that the relationship is linear. In equation form, one gets:

$$\frac{dL}{dt} = \frac{\pi_L}{\tau_L}L = \frac{1}{\tau_L}\left(\frac{p}{w}\frac{\partial Y}{\partial L} - 1\right)L \qquad [hr/yr] \qquad (7)$$

As long as an additional unit of labour yields an (expected) net gain, that is, p dY > w dL or pY > wL/(1-α), more labour will be hired at a rate proportional to the marginal labour productivity expressed in wage units p (∂Y/∂L) /w. [3] The response parameter $\tau_L$ (tau L) represents labour market frictions and inertia. The potential labour force is assumed to be 50% of the EU20-population.

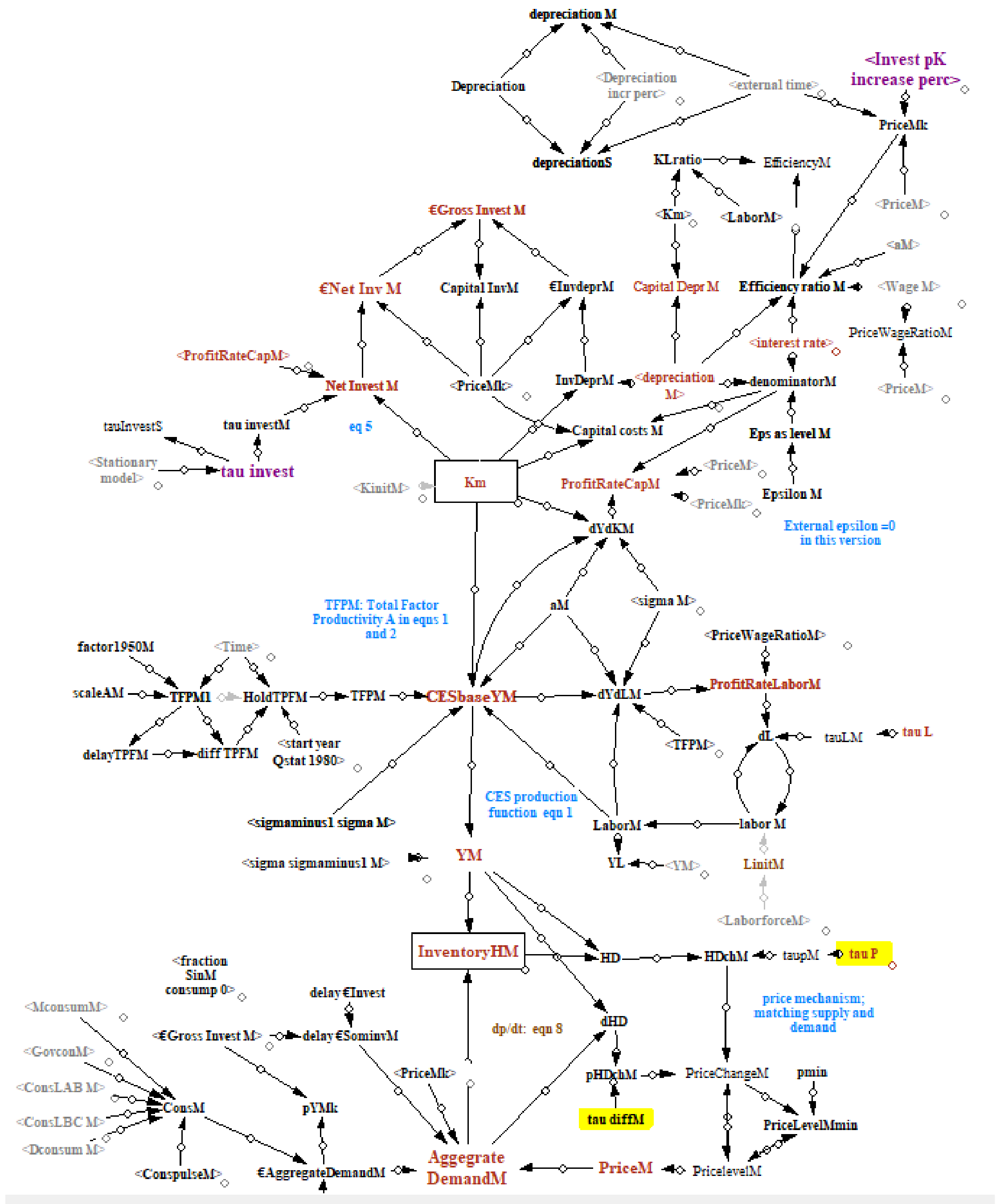


*Figure 2.1 Economy module*

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[3] In case of a CD function for which ∂Y/∂L = (1-α) Y / L, it is seen that $\pi_L = 0$ for (1-α) p Y = w L at which level the net profit rate from labour force expansion has fallen to zero. This is the equilibrium value to which the simulated economy tends to go.

The above equations describe the dynamic processes of investment and labour force and the balance equation for the different economic sectors. This description does not assume a balance of prices and volumes in markets at the end of a period. Instead, the tensions between supply and demand generate changes in the next period. The model is therefore primarily aimed at describing the non-equilibrium behaviour of the financial economic system. The model comprises some other dynamic features, which are discussed below: price changes from supply-demand mismatch, changes in interest rate, changes in asset prices and money creation by banks and government institutions (like ECB).

## 2.2 Price, inflation

The price adjustment mechanism drives supply and demand towards temporary equilibrium. (Hallegatte *et al.*2008). If actual output ('supply') Y differs from the Aggregate Demand D (Figure 2.1), being the sum of consumption and investment, there is a surplus (inventory) or a shortage (unmet demand) H (Inventory H). Mathematically: dH/dt = Y – D. For Y > D, the inventory H increases and as a result the price p will decline, which permits consumers to purchase more goods and service at the same wages (and the same amount of money in circulation). For D >Y, the reverse will happen. In equation form:

$$\frac{dp}{dt} = -\frac{p}{\tau_p}\,\frac{H}{D} \qquad [€/G/yr] \qquad (8)$$

with $\tau_p$ (tau p ) again the response parameter representing the inertia and herewith the 'stickiness' in the system. The inflation rate is calculated as the derivative of the price, i = dp/dt.

In this mechanism, the level of inflation is dependent on the quantity of money in the system via many different routes. In addition to interest, taxes and government spending, the creation of money by private banks in lending is the most important factor. A second important factor for the level of inflation is the employment level. In case there is no full employment (90%), wage levels will not increase strongly and the impact on inflation is moderate. In case of full employment, wages will rise sharply and provoke higher inflation levels.

## 2.3 Wage levels

A similar adjustment mechanism is supposed to operate on the labour market. In a market economy, a shortage of labour will drive up wages whereas a surplus will do the reverse. The wage level w is thus assumed to be dependent on the employment level (Hallegatte et al. 2008):

$$\frac{dw}{dt} = w\,\frac{(e - e_{des})}{\tau_w} \qquad [€/hr/yr] \qquad (9)$$

The wage w is assumed to be constant when the actual employment level equals a socially acceptable or desired employment level, which is associated with full employment equilibrium (Figure 2.2). If actual employment e exceeds this desired level of employment $e_{des}$ in a tense labour market, w tends to rise more sharply, as a result of the then increasing value of the factor Mismatch Employ with a factor '2'. When employment falls below the desired level, wages will start to fall. $\tau_w$ is again a response parameter (tau wages).

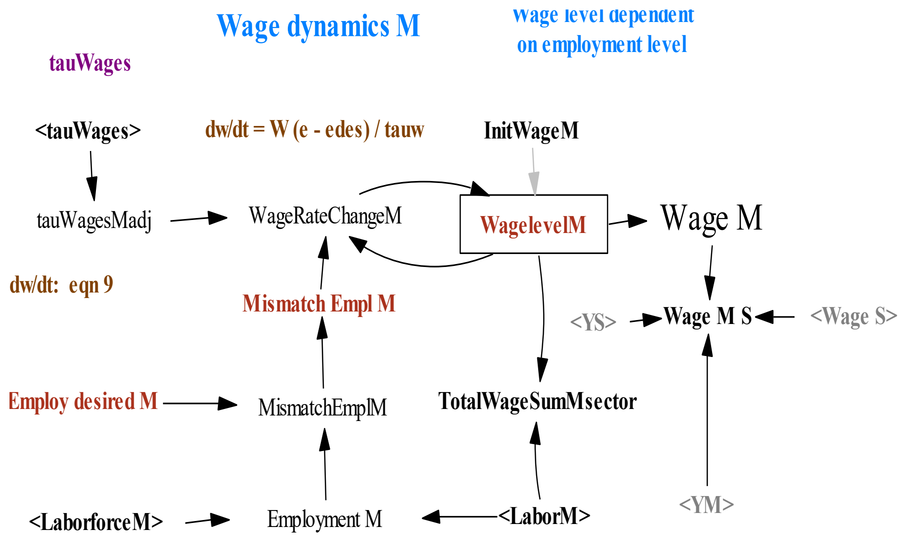



*Figure 2.2 Wage dynamics*

## 2.4 Sector shift

If employment levels in the M or S sectors diverge significantly, the labour capacity shifts from the lower employment sector to the higher employment sector. This is achieved via the Mshift mechanism in the Labour and Initialization module on the far left side of the Vensim model sheet.

## 2.5 Labour – Capital substitution

The constant elasticity of substitution (CES) production function makes it possible to model the ongoing trend towards rising labour productivity through the substitution of labour by capital. This shift is determined by the value of σ in equation 1. In the model, the substitution rate is determined depending on the employment ratio (Figure 2.3). It assumes that labour substitution is higher with higher employment ratios (labour scarcity). Figure 5 shows the resulting value for alpha, i.e. the share of total production that is allocated to the factor of production capital.

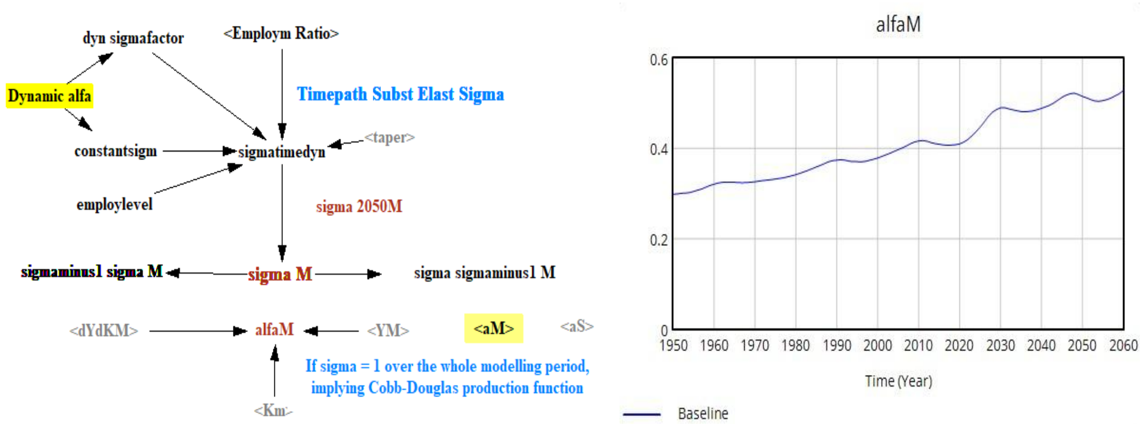



*Figure 2.3 Labour- capital substitution (alfa) in CES-function depending on employment level*

## 2.5 Interest rate; dual causation

In modelling the interest rate, the following observations of Werner (2012, p.1-17) have been taken into account:

- The causality of the interest rate runs in two directions: *"in terms of timing, interest rates appear as likely to follow economic activity as to lead it"* (Werner 2012:4). Money creation, by the net increase of the volume of loans, increases the money stock and thus drives down the interest rate. Vice versa, investments both in productive firms (via shares) and in non-productive assets reduce the level of liquidity, thus increase the interest rate.
- In creating new money when granting loans by banks, be it for productive or non-productive use, money scarcity is structurally evaded and the corresponding increase in interest rate as market regulating variable thus does not occur.
- Lower interest rates are not necessarily able to stimulate the economy. If the key variable driving growth is credit for GDP-transactions and this is not growing, GDP will not grow when the credit is used for unproductive purposes (for example housing).

The role of the interest rate in the total system is thus at least complicated and ambiguous. Given the observation that the interest rate can be cause and effect at the same time, the interest rate is derived from both supply, as given by the stock of money M, and demand for money as given by the level of investments $I_{total}$ (€Investment); Figure 6. Setting an initial value for the interest rate ρ, the relative change in the natural interest rate is assumed to be proportional to both the change in investments I, relative to the money stock $M_{liq\ ass}$ (liquidity; in Financial System: Assets) and the relative change in this liquid money stock $M_{liq\ ass}$:

$$\frac{d\rho}{\rho} = d_{demand}\frac{d\,I_{total}}{M_{liq\ ass}} - d_{supply}\frac{d\ M_{liq\ ass}}{M_{liq\ ass}} + d\,P_{ir} \qquad [-] \qquad (10)$$

The second, (supply side) term describes relative changes in the interest rate by relative changes in the overall available liquidity, for example by money creation or selling / buying of bonds. The money stock $M_{liq\ ass}$ equals the 'liquid assets' (deposits) of the consumers categories LAB- and LAD-consumers.

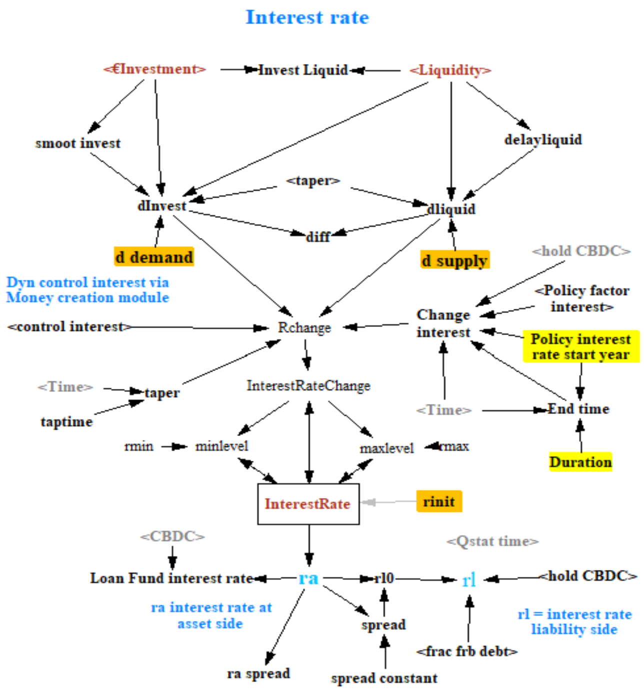



*Figure 2.4 Interest rate*

The first (demand side) term describes the change of the interest rate as resulting from the change in firm investments. These investments are financed by retained earnings, equity (shares) and bank loans, which together make up the above-mentioned credit for GDP transactions. As Werner (2012) points out, the availability of this credit is an important determinant of the level of productive investment. The increasing demand for money through the narrower, more constrained channels of bank loans and shares is more likely to lead to liquidity scarcity and thus in a sharper rise in interest rates. In order to take account of this partial effect, the (relative) increase of the interest rate is considered to be proportional to the relative change of investment d $I_{total}$.
The total change of the interest rate is derived as a weighted linear combination of the rates at which the initial liquid assets $M_{liq\ ass}$ become available through these two different channels. Herein, $\mathbf{d_{demand}}$ and $\mathbf{d_{supply}}$ are the respective (important) weighing coefficients to empirically balance these different responses (Figure 2.4).

### Interest policies

In contrast to the first two terms of eqn.10, which represent the '*natural' interest rate* as based on the actual state of macro-economic parameters, the third term $P_{ir}$ (policy interest rate; Figure 2.4) represents the option of introducing a policy driven increase or decrease of this 'natural' interest rate. This *interest rate policy* intends to control economic activity, in particular in order to control inflation. By means of eqn.10, this policy option can be simulated, while keeping the dynamical behaviour of the system (as given by the first two terms of eqn. 10) intact.

There are two options for interest policies:

- By setting the policy interest rate start time (Pol int rate start time) in the Dashboard, or in the righthand-side of the Interest rate module to for example 2022 and setting Duration on for example 4 years, the natural interest level is increased according to the policy factor from 2022 to 2026. This simulates the interest policy of the ECB for that period.
- Bij setting the Interest policy in the Dashboard to '1', the interest rate is increased dynamically in case the inflation level is higher than the targeted (2%) inflation level. This is in particular relevant in combination with inflation control by centralized ECB-money creation. In case of too low price levels (deflation), additional money is brought into circulation, in case of too high price levels, the policy interest rate is increased with a Dynamic Policy interest rate factor ( Dyn IR factor).

## 2.6 Asset prices

A key mechanism in the model is the credit creation by private banks to an ever larger extent for nonproductive uses, notably for real asset (house) mortgages and financial market transactions (Bezemer and Hudson, 2016). House mortgages are determined by house prices, and at the same time imply money creation and thus increase of liquidity, which in turn causes house prices to increase further. This mechanism was posited by Goodhart and Hofmann (2008) who considered the link between money, credit and house prices to be multi-directional: "money growth has a significant effect on house prices and credit; credit influences money and house prices, and house prices influence both credit and money". This was recently confirmed by an empirical study of the (Dutch) Central Bank (Eijsink and van Dijk, 2023). The study showed that the '*ability to pay'* is the most determining predictive factor for housing prices (Figure 2.5). This ability is a fraction of the net -real disposable-income and is somewhere in the range between 30 % and 50 %. It reflects that a certain, limited fraction of net income, the 'residential quote', can be spent on housing costs (mortgage repay and interest).
Nevertheless there is a tendency to spent a larger fraction on housing than realistically affordable, implying that in addition to the 'ability to pay' (AtP) there apparently is a higher level of '*willingness' to borrow* (WtB)*'*. It is driven by the anticipation of future increase of income or by expectations on ongoing increase of housing prices, as suggested by Levin and Wright (1997) and Meen (2002). This willingness to borrow parallels the willingness to lend of private banks, which have commercial

interests in lending larger volumes of newly created money. This ‘willingness to lend’ (WtL) and/or borrow will result in additionally increasing asset prices, which generate over-indebtment.

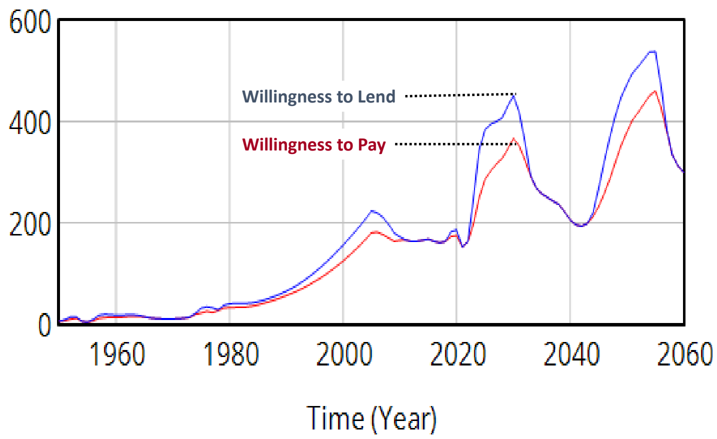



*Figure 2.5 Asset price as the sum of the Ability to Pay (AtP) and Willingness to Lend (WtL)*

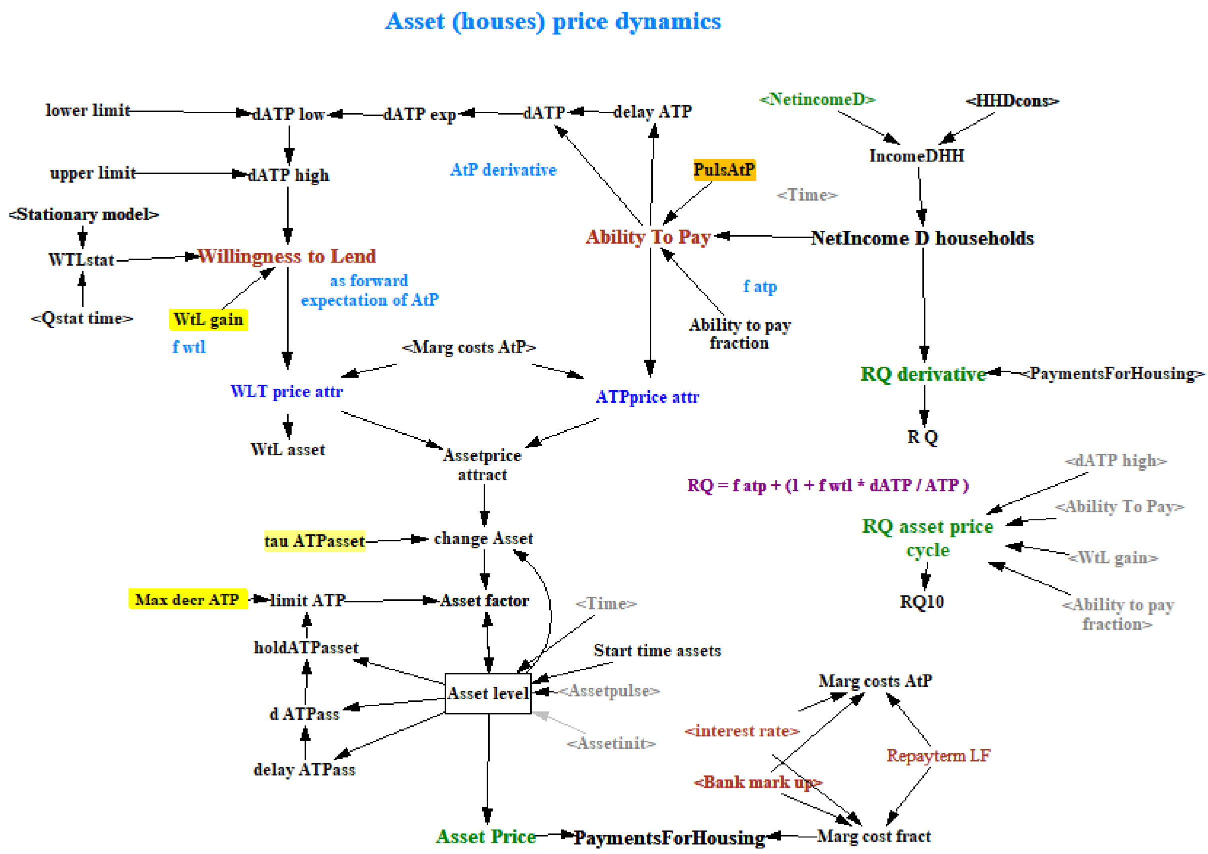



*Figure 2.6 Asset prices*

In the asset price module , key variables are the proportion of net income, which is considered to be indicative of the amount of mortgage financing and repayment costs that mortgage holders can always pay; the *ability to pay* in Figure 2.6. This value is set to 0.35. The willingness to pay factor determines the amplitude of the fluctuations in asset prices. This value is set to 2.

It is assumed that households can spend at least a fraction $f_{atp}$ of their net income on financing their house and on top of that anticipate income growth that will continue for $f_{wtl}$ years to come. The mortgage has to be repaid in $t_{repay}$ years (Repayterm). To formalize this mechanism, the asset price $p_{asset}$ is calculated as:

$$p_{asset} = \frac{(\mathrm{AtP} + \mathrm{WtL})}{(\tau_{repay} + \rho + \mathrm{Bm})} = \frac{(\mathrm{AtP} + \mathrm{WtL})}{f_{costs}} \qquad \text{€/household} \quad (11)$$

with $\mathrm{AtP} = f_{atp} \cdot (\text{net income})$ and $\mathrm{WtL} = f_{wtl} \frac{d\,AtP}{dt}$ ; $p_{asset} = p_{AtP} + p_{WtL}$

Herein, ρ is the interest rate and the bank markup Bm is the additional fee required by the bank (2 % in current computations). The denominator of eqn. 11 is the Repay and Interest Finance fraction ($f_{costs}$) Together with the Asset price, this gives the amount of Payments for Housing.

As shown in Figure 2.6, the Residential Quote is calculated as the Payments for Housing / Net income D consumers. Herein, the small effects of delayed fluctuations of the interest rate are comprised. Omitting these effects, the Residential Quote can also (theoretically) be written as:

$$\text{Residential Quote} = f_{atp} \left(1 + f_{wtl} \frac{d\,\mathrm{ATP}}{\mathrm{ATP}}\right) \qquad (12)$$

as the Ability to Pay is derived from net income and the additional Willingness to Pay subsequentially derived from the Ability to Pay. The Residential Quote, and herewith the (financial) crisis mechanism to be discussed below, thus is primarily linked to the ability to pay, and thus of net income.

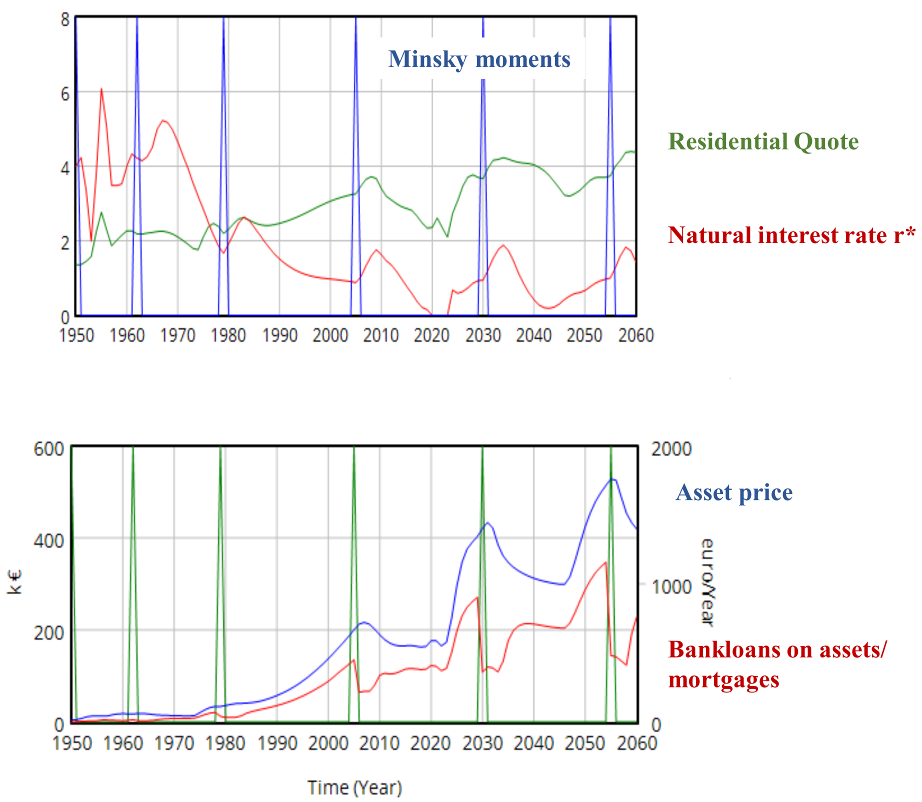



*Figure 2.7 Computations for the Residential Quote (RQ = fin costs / net income), natural interest rate r*, asset price and bank loans on assets (incl mortgages)*

The Residential Quote plays an important role in the model, as it activates the 'Minsky' moment to be discussed later, as soon as mortgage holders can no longer repay their debts. At that point, the Residential Quote exceeds a certain threshold level. Since the Residential Ratio follows from the asset price development discussed above, this value represents the business cycle of the system as a whole,

Three mechanisms with respect to the Residential Quote can be applied:

1 The RQ as the fraction of the net income which is spent on asset costs, i.e. costs of housing (mortgages), as represented in Figure 2.7. Rather than considering the absolute RQ-maximum level, the temporarily optimum which results from the inherent asset price cycle (boom-bust cycle). This maximum is found as the derivate of RQ =0. In this way, RQ derivative is less sensitive to the overall decreasing trend of the natural interest rate.

2 The second option is to consider the absolute level of the RQ. The 'Minsky-moment' is reached when a certain maximum, given by threshold level is exceeded (approx. 40%) RQ maximum.

3 The third option is to derive the Minsky moment from the asset price cycle only, according to eqn.12. Also in this case of RQ apc the Minsky moments are not fading out in the longer term as a result of the decreasing trend in the interest rate, in combination with the subsequent strong increase in net income.

As it is unclear how the decreasing trend in interest rate (and subsequent increase in net income) will affect the overall macro-economic system, all three RQ-options can be applied in the model (choices 1,2 and 3 in Figure ). The differences between the three methods are small and only become manifest in the years after 2040 with further decreasing interest rates.

Option 1 will be considered as the standard option; the Minsky moments thus are derived from the relative, rather than the absolute maxima of the RQ over time.

## 2.7 Bank loans

In the module 'Bank loans' the required amount of bank or mortgage loans is calculated. The money needed is partly newly created by expanding the banks' balance sheets, partly based on existing money through peer-to-peer lending, through banks (Figure 2.8)

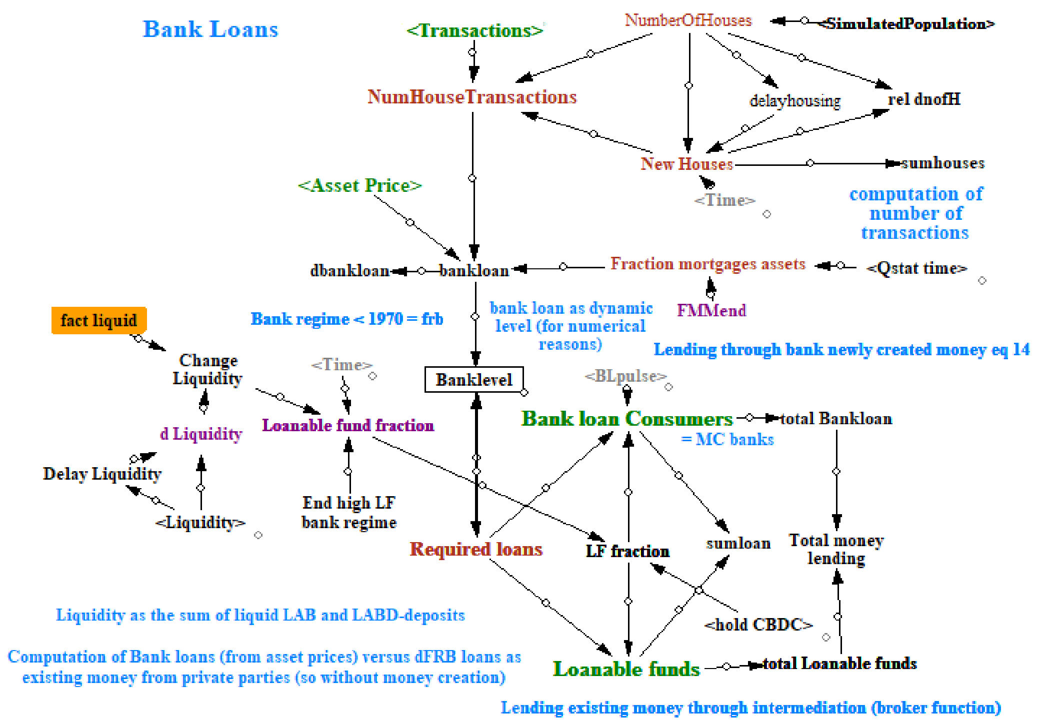



*Figure 2.8 Bank Loans*

The sum of yearly number of existing house transactions and new houses ($n_{trans}$) is assumed to be a fixed fraction (transactions: 5 %) of the number of households plus the new houses added to the housing stock.

In asset transactions on average only a fraction $F_b$ (fraction mortgages assets) of the asset price needs to be financed additionally (Figure 2.8). The remainder of the asset price is financed by selling other / earlier assets. In the current computations, $F_b$ has been estimated as 30 %. For all asset transactions in a given year, the total amount of required loans $BLF_D$ is thus given by:

$$BLF_D = n_{trans} \,.\, p_{ass} \,.\, F_b \qquad (13)$$

The required loans $BLF_D$ consists of lending of newly created money from banks $BL_D$ and lending of already existing money as 'loanable funds' $LF_D$ from the financial markets (private equity etc). The fraction of loanable funds in the total amount of lent money is assumed to be proportional to the relative change in financial market liquidity (the LAB- and LABD-deposits). At increasing liquidity, lending will be increasingly based on existing money from loanable funds. With the proportionality given by multiplier $A_m$, this 'loanable fund fraction' , or LF-fraction thus can be defined as:

$$F_{loanf} = A_m \,.\, \frac{dM_{liq}}{dt} \qquad (14)$$

The loanable fund fraction before 1970 is increased (average 0.3) relative to the level after 1970 (average < 0.1) in order to account for the then larger share of existing money (loanable funds) in the financing of investments and mortgages. After 1970 the digitalization and liberalisation of banking gave rise to a larger share of new money creation in private bank lending, thus lowering the relative share of loanable funds.

The amount of loans given by banks $BL_D$ to D-consumers (Bank loan) and herewith the amount of newly created money $MC_{banks}$, is given by:

$$MC_{banks} = BL_D = (1 - F_{loanf}) \,.\, BLF_D \qquad (€/\text{year}) \qquad (15)$$

Although this asset price mechanism primarily refers to real assets, such as housing, the same mechanism is expected to hold for other assets, including resources and financial assets. The prices of these assets are expected to behave similarly and the required bank loans will have a similar effect within the financial system.

### Endogenous private bank money creation

In the model, the amount of money which is lent to D-consumers ($BL_D$), firms and the government not only originates from banks but also from private equity, pension funds and the like. The latter category is represented by the deposits of the LAB- and LAD-consumers as 'financial markets'. Lending from banks and from financial markets differs fundamentally in whether the money is credited by existing money from earlier savings or by the creation of new money 'out of thin air':

- Financial markets (liquid deposits of LAB- and LABD- consumers) are assumed to provide credit in the form of *existing money*. Without creation of new money by banks, the overall amount of money in the system remains constant and an increasing demand for money can be expected to result in decreasing liquidity, an increasing (natural) interest rate and a new equilibrium between money demand and supply. Lending of existing money is denoted as lending on the basis of '*loanable funds*'.
- Banks provide credit on the basis of *newly created money*. This is possible because the 'money' on which the societal system is based is not 'real money' but only a 'claim on real money'. The scale on which banks can create loans is limited by the requirement that the 'capital ratio' (in Bank assets / equity), that is, the ratio between equity (own capital) and the sum of the outstanding loans of the bank, does exceed a certain minimum value; in the model

a capital ratio of 5 % was applied. Within this limited constraints, banks are free to create new claims by elongating their bank balance sheet and thus create new ‘money’. This money is both credited to the borrower as a deposit at the liability side and as a debt of the borrower at the asset side of the balance sheet, thus maintaining the required balance.[4] In case of the creation of new money, financial market liquidity increases correspondingly. In this case of money creation, there is therefore no increase in interest rate to equilibrate money demand and supply. As a consequence, the costs of assets (mortgages) remain low, which will result in further increasing asset prices.

In Figure 2.9, the overall money creation by commercial banks is given in the adjacent module Bank debts & Liabilities by the sum of the respective (total) Bank loans to D-consumers, firms and government:

$$MC_{banks} = BL_D + BL_{firms} + BL_{gov} \qquad (€/year) \qquad (16)$$

The new money is created within the constraints mentioned above. In practice, this limitation can be circumvented (Werner 2016). MC banks represents the overall money creation without accounting for repayments. The net money creation, from which the repayment of loans is subtracted for respectively consumers, firms and government, is given by Net MC Banks.

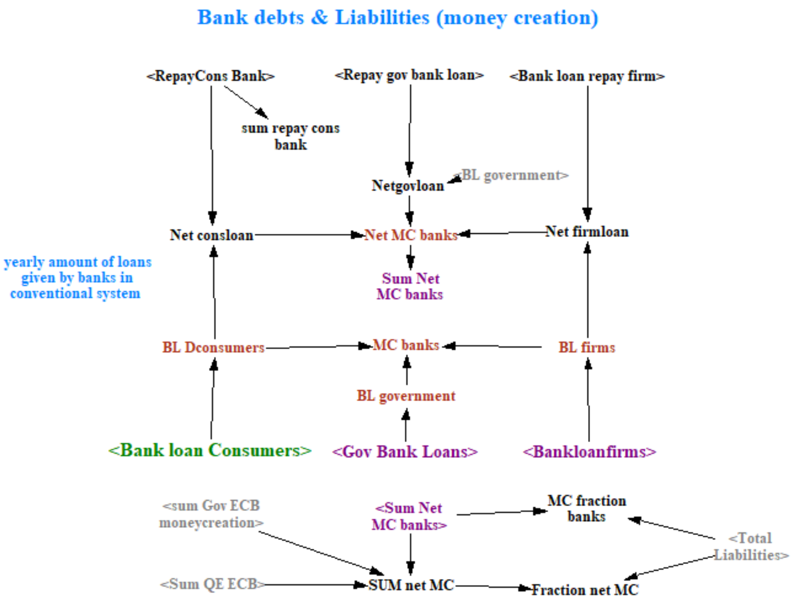



*Figure 2.9 Overview Bank debts and Liabilities*

## 2.8 Minsky moment; financial crises

Already in 1982, Minsky (1982) described this ‘archetypical’ mechanism as the main characteristic of financial crisis. As already indicated, the mechanism not only holds for real estate but also applies to financial investments and financial assets (like shares) in general, as described by Minsky. Aiming for low debt-to-(bank) equity and high profit-to-interest ratios, bankers start to finance more risky investment projects, which causes an increase in asset prices. Eventually, assets can no longer be traded at a profit, debts can no longer be serviced and the(‘Minsky’-) moment of crisis has been reached (Minsky 1982,p.33; Keen 2013). Minsky concluded more general that “a capitalist economy

4 The banks’ income or bank fee’ is the difference (‘spread’) between interest rate $\rho_l$ at the asset-side of the balance sheet and $\rho_d$, at the liability side.

generate financial relations that are conducive to instability and that the price and asset-value relations that will trigger a financial crisis in a fragile financial structure are normal functioning events" (Minsky, 1982.p.34).

Asset price crisis and herewith financial crisis is initiated once the overall residential quote, covering the actual (AtP + WtL-asset price) reaches the critical level at which a substantial fraction of households no longer can pay the mortgage costs. As this happens, the only subsequent (model-) assumption then is that the asset / housing market will respond to the high asset price level with a reduction of transactions $n_{trans}$ (transaction from 5 to 2.5 % per year). According to eqs. 13-15, this will result in a lower level of new money creation, thus a relatively lower level of liquidity, a subsequent higher interest rate, lower investments, lower physical production, lower wages / net income, thus finally also lower ability to pay (AtP). According to eqn. 11 this decrease in ability to pay AtP will result in a strong decrease of the willingness to lent WtL-component of the asset price. This then results in a significant decrease of the total asset price, which reinforces a further decrease through the same vicious mechanism.
The downward spiral turns into profound financial crisis once the decrease of the asset price becomes significant and the loss of collateral value becomes larger than the bank capital ratio. In that case a fraction of commercial banks will go bankrupt and will call for recapitalization by the government. The subsequent, very significant increase in government debt has to be repaid by increased taxation and / or less government spending (austerity policy). This further reinforces the downturn of the boom-bust cycle.

The critical level of the Residential Quote might be set at a certain absolute level, for example 40 %, which would mean that households spend 40 % of their net income to housing (mortgage) costs. As this critical level is reached, the yearly number of house Transactions is expected and assumed to decrease from 5 % to 2.5 % (0.05 to 0.025). As this decrease implies the same reduction in the number of new lending (mortgages), and thus less money creation, the liquidity in the system decreases, as a result of which the interest rate increases. The inherent boom-and-bust tendency in the real financial system thus is simulated by the model primarily on the basis of the circular link between increasing costs of housing (willingness to pay; residential quote) – market driven decrease of house transactions — decreasing money creation –( decreasing asset prices) – less increase of total liabilities / liquidity – increasing interest rate – less investments – less physical production – lower wage/ price levels – lower net income – decreasing asset prices.

However, as shown in Figure 7, the asset price mechanism itself (eqns. 11 and 12) generates an asset price (boom / bust) cycle. The speculative WtL-component drives the asset price to a level higher than the net income proportional AtP-level. How this results in the business / boom-bust cycle is demonstrated in Figure 2.10:

1 By providing higher mortgages at the rising asset price, more money is created, which will initially increase liquidity, after which interest rates will fall and then investments, economic activity and net profit will increase.
2 In the second instance, the <u>increase in</u> the asset price, and thus the inflow of new liquidity, is at its maximum, while at the same time the increasing investments require more liquidity. As a net result, interest rates are starting to rise again. With the now rising interest rates and the still rising asset price, the Residential Quote continues to rise as well.
3 Upon reaching the maximum value of the Residential Quote (e.g. around 1985 and 2005), the Minsky moment is reached, the asset price starts to fall, after which for a certain (5 years) period the number of active transactions is reduced from 5% to 2.5%. Because this immediately halves the amount of newly created money, liquidity decreases and interest rates rise even further.
4 After the end of the Minsky period, transactions will increase to up to 5% per year, restoring the inflow of new money to its original level. As a result, interest rates immediately start to fall. Around 2020, this decline is extremely strong, as a result of the QE policy in the previous decade, in which liquidity was increased by a net 5000 billion euros. In response to the low level of interest

rates, investment, total economic activity (pY) and net income of (due) D consumers will initially increase.
As indicated above, interest rates will rise again in the second instance, the Residential Quote will reach its maximum and a new Minsky episode will be reached.

The financial cycle is thus triggered by the significant fall in house and asset prices, due to:
- the assumed market reaction in the number of housing or asset transactions as soon as the cost of housing (residential quote) has become financially unsustainable.
- the self-reinforcing speculative price cycle generated by the pro-cyclical nature of the system, where price increases cannot be maintained and inevitably result in self-reinforcing price decreases.

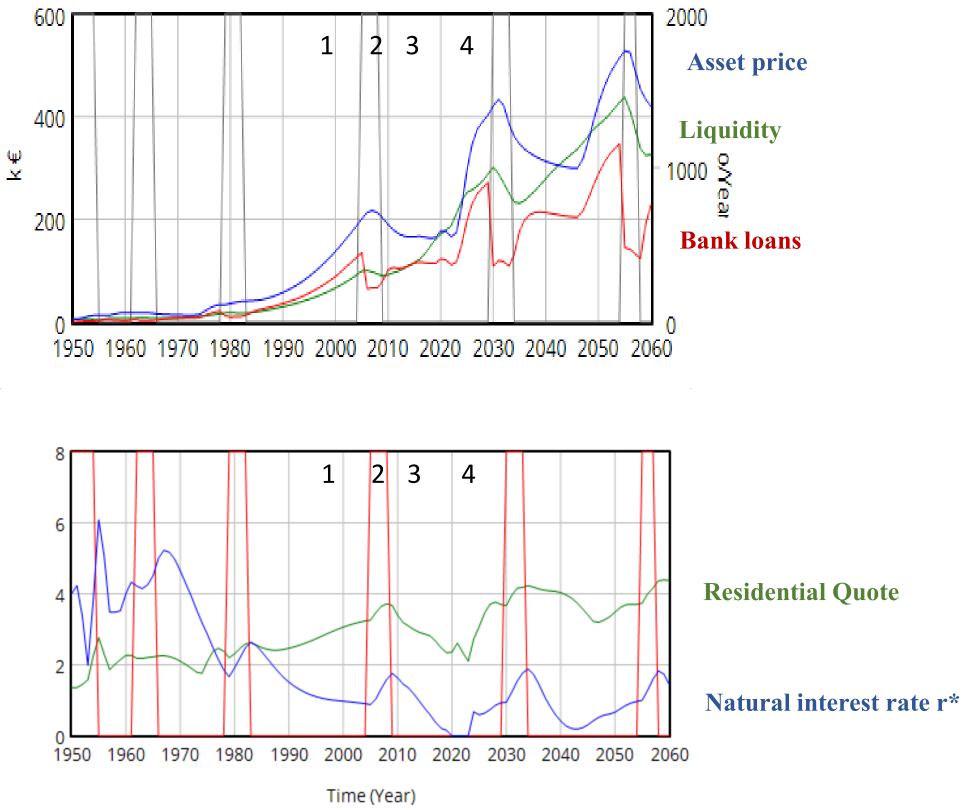



*Figure 2.10 , Interest rate, Residential Quote, Asset price, Investment (monetary), Bank loan on assets, Liquidity and Minsky episodes (reduction of transactions from 5 to 2.5 % per year).*

Against this background, instead of exceeding an absolute level, the moment at which a significant proportion of indebted consumers can no longer service their debt will be derived from the maximum RQ level. Given the asset price mechanism, a slowdown in the increase in net income, given the overall diminishing returns in the system as a whole, will reduce the 'ability to pay', as a share of the asset price. The resulting fall in the asset price will lead to fewer bank loans, and thus less money creation. Dominated by the level of the asset price, and despite the subsequent rise in interest rates, the RQ level will also reach a maximum. Once this maximum is reached, the number of transactions will start to decrease and with that the Minsky period begins.

This 'maximum RQ' approach thus aligns the Minsky moment with the inherent dynamics of the (modelled) financial system as a whole.

In Figure 2.11 the computational scheme for the derivation of the Minsky moment from the alternative Residential Quote derivative is presented. The derivative of the RQ derivative level are computed as respectively deriv RQdrv.. For the RQ  based on the asset price cycle only (excl interest rate) this is deriv RQapc. As soon as the derivative becomes (close to) zero or negative, the RQ-maximum is reached, indicated by the change from positive (1) to zero / negative (0). At this moment, indicated by Minsky drv, the Minsky episode starts. From the Minsky 0 / 1 signal, the number of transactions (5% / 2.5%) is derived. After the appropriate RQ-function is chosen in Select 1 2 or 3, the Minsky moment is translated into the decrease of the number of house Transactions. The length of the episode is created by a smooth-function (RQ window). The width of the Minsky window determines the recapitalization of  banks by the government (Figure 2.12).

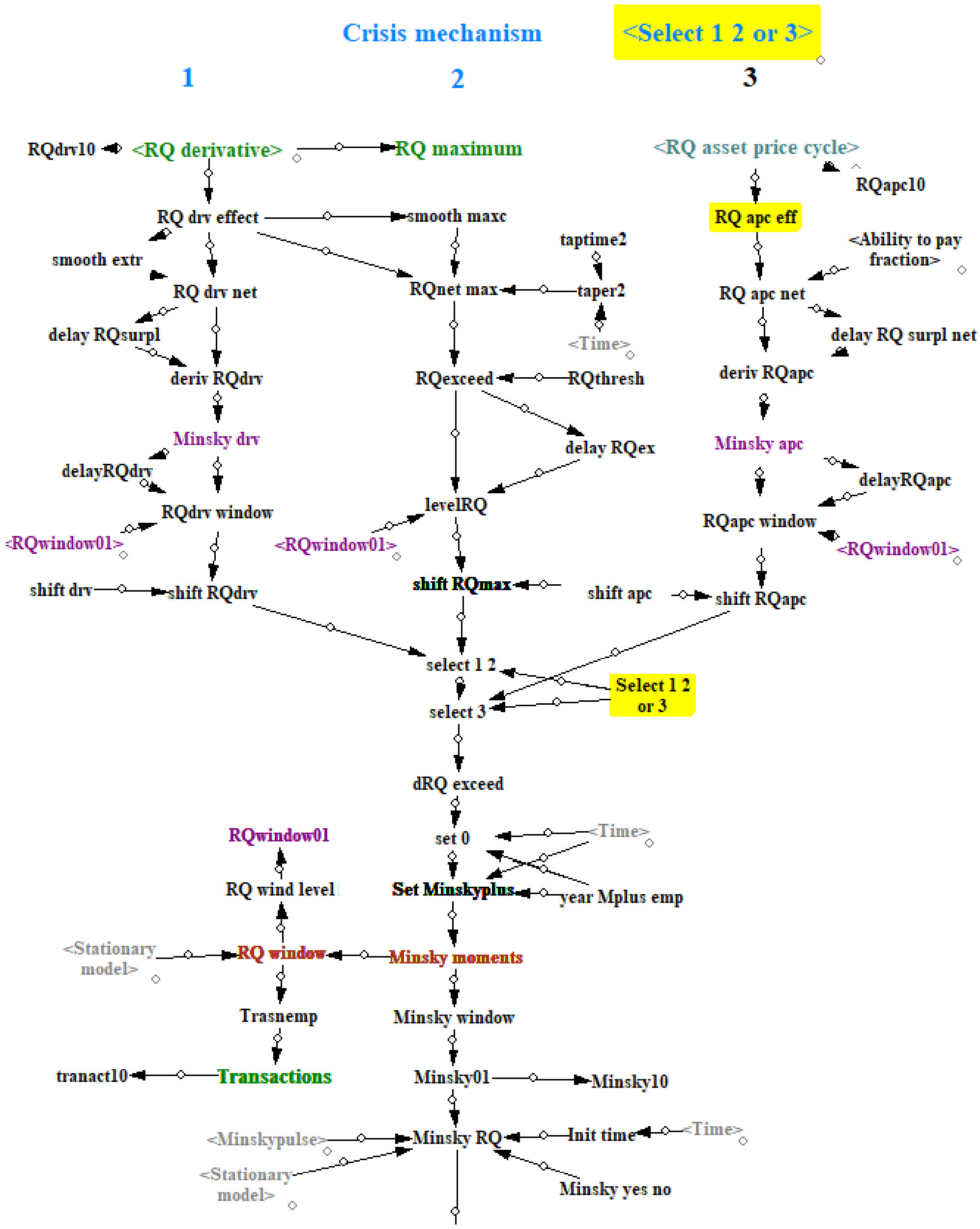



*Figure 2.11  Derivation of Minsky moments from the three alternative RQ-developments.*

## Crisis mechanism

During the Minsky period, the reduction in the number of asset transactions reduces the total amount of bank loans on assets, so that the complete sequence described above leads to an economic recession. (Figure 2.11). If the amount of non-redeemable loans minus the corresponding reduced value of collateral assets exceeds the bank buffers, banks risk failing and need to be bailed out by government recapitalisation (Figure 2.12). This then has additional negative consequences, as the recapitalisation is paid for by tax increases, which further worsens the economic situation.

In case of crisis, a default fraction (10 %) of the bank debts of firms (Bankdebtfirm) and consumers (Bankdebtcons) is assumed to be defaulting (Figure 2.11). (Private) banks have to be refinanced for this amount of money by the government. The levels hold BdF and hold BdC are used to sample the debt levels by means of a pulse which is triggered by Minsky, The resulting amount of money Govrecap is to be transferred from the government deposit to the bank-reserve (deposit) in the financial system to compensate for the losses on the asset side of the bank balance sheet; see below. The non-recoverable debts are written off from the debt of the D-consumers with the amount Govrecap.

Along the same lines, a fraction of the debt obligations which D-consumers have to the LAB and LABD-consumers (peer to peer lending of existing money; loanable funds) will as well default in case of crisis. This fraction of the Loanable Fund debt is written, without any concern for the government. The money is 'transferred' from the LAB and LABD-lenders to the D-consumers. (see financial system below).

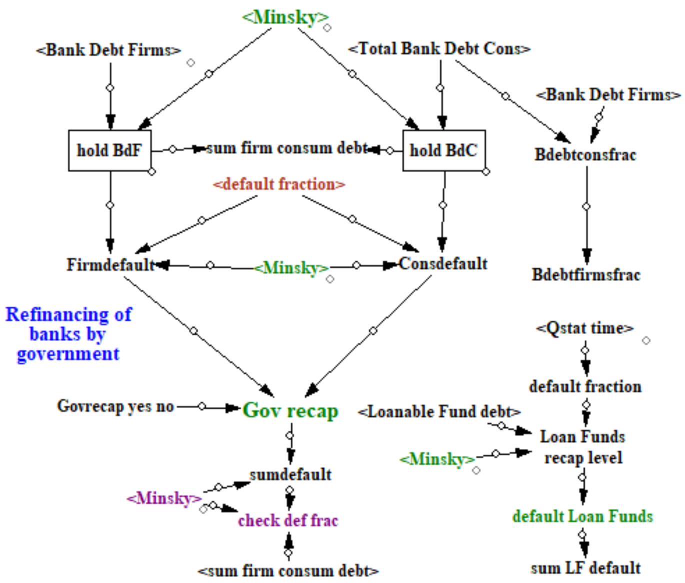



*Figure 2.12 Crisis mechanism; recapitalization by government.*

The crisis mechanism thus can be summarized as follows:

1. In reaching the threshold level of RQ (or its corresponding optimum in the asset price (boom-bust) cycle, the Minsky moment is triggered.
2. In the next step the number of house transaction decrease for a certain period from 5% to 2%; as a consequence less money is created, liquidity will decrease, which results in increasing interest rate at first and decreasing levels later. The decreasing asset prices imply decreasing collateral value for banks through which they are assumed to become insolvent.
3. Given bank-insolvency, the government has to recapitalize the banks for a given fraction of their defaulting) assets. The money is raised by the immediate emission of bonds. (A part of the required money comes from new money creation by (other) banks.
4. The increased government debt is to be repaid by taxpayers.

In the current version of the model steps 2 (decreasing asset price levels) is combined with the following step 3 (recapitalization of defaulting banks). Many numerical experiments have been made with a sequential process, in which banks default only after substantial price drops, However, comparison of model results with the available statistical data indicate that the processes 12 and 3 are simultaneous, or at least occur within a short, necessarily overlapping time frame. Only under this condition, the model results match the statistical data.

## 2.9 Externalities; increasing capital costs

External effects, such as the increasing scarcity of resources, are modelled by increasing the price of capital $p_K$ compared to the general price level p. This can be effectuated by setting the Invest pk increase percentage and the start year extern in the dashboard. For example, by setting this percentage increase to '25', from the year 2026 onwards for a 10 years period until 2036, the calculations will be carried out with investment costs 25% higher than the general cost level p in the M-sector (in the upper right part of the economy module in Figure 2.1). The results are shown in Figure 2.13:

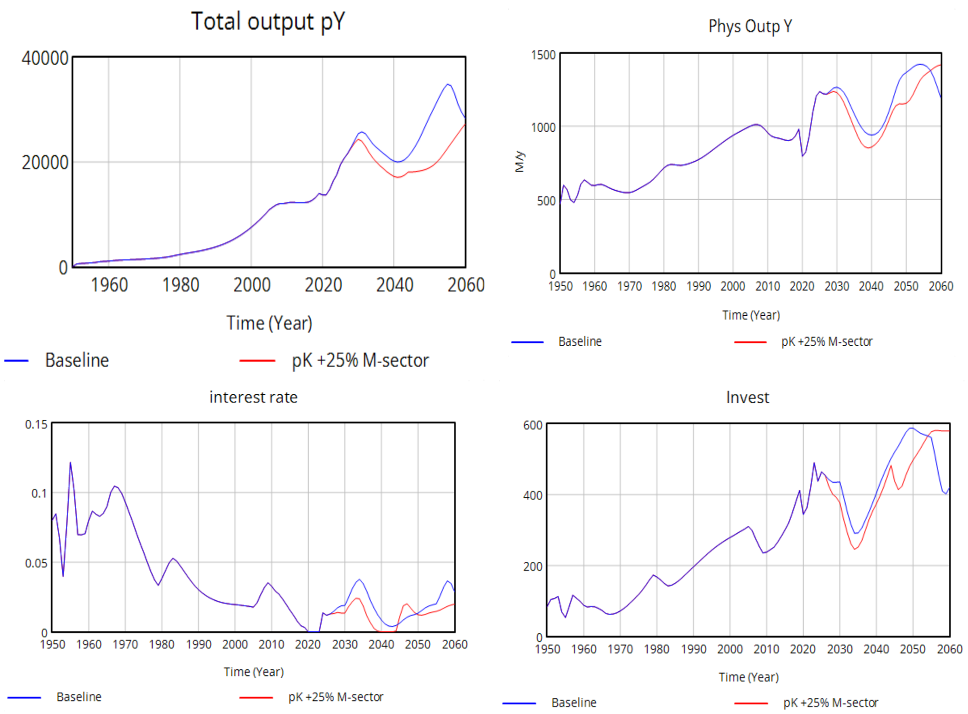



*Figure 2.13 Model results for the baseline (pk = p) and in case investment costs pk are 25 % higher than the general price level p, during the period 2026-2036.*

The Eurozone is assumed to be a closed economy. So the increased cost of capital, and therefore the cost of production, must be generated within the system itself. In the case of imports from outside, these imports must be compensated by exports of approximately the same volume, which must be produced within the system.
As shown in Figure 2.13, the higher capital price results in a calculated lower level of capital, which means that total production, both physical and monetary, is lower. At the lower level of physical (and monetary) investments, (unused) liquidity is slightly higher and the (natural) interest rate is subsequently lower. Employment decreases in the Manufactor-sector and increases in the Service-sector, which results in a shift of labour-capacity from the M- to the S-sector (mShift).

## 3 Financial system

The *financial system* is modelled as an aggregate bank and thus has the structure of a bank balance sheet, with assets and liabilities (left and right hand side). The deposit holders are private (production) firms, government, a (central) bank and the indicated four groups of consumers. The flows of money in the financial system is governed by the dynamical model behaviour. Given these flows, the amount of money and debt in the model is continuously numerically evaluated for the nine deposit holders which were accounted for in the model. In Table 1, the nine columns represent these nine categories of liabilities, corresponding with the right hand liability side of the Aggregate Bank-balance sheet in Figure 1. As indicated in the first row of Table 1, the first seven deposits are listed as positive, as they are assets to the various deposit holders. From the perspective of the bank, these deposits are liabilities, which will reduce bank equity (-D). The various types of assets are given in the first column of the balance sheet. The deposits are stocks, which buffer the dynamical behaviour of the flows. In case of more inflow then outflow, the level of the stock-deposit increases. Stock-Flow consistency is continuously controlled, which means that no money is lost from the system. The amount of money only increases through money creation (commercial banks or Central Bank) and decreases (annihilates) through repayment of loans.

| **Balance-sheet matrix** | **Consumers** | | | | **Firms** | **Firms** | **Government** | **Central** | **Bank(s)** | **Σ** |
|---|---|---|---|---|---|---|---|---|---|---|
| | **M-consumers** | **D-consumers** | **LAB-consumers** | **LABD-consumers** | **Manufacture** | **Services** | | **Bank** | | |
| | low income non-saving | low labour income inDebted | Labour / Assets/ Bonds | Labour/Assets/ Dividends/ Shares | | | | | | |
| | | | ≈ Financial markets | | | | | | | |
| Deposits | + $D_M$ | + $D_D$ | + $D_{LAB}$ | + $D_{LAB}$ | + $D_{firms}$ | | + $D_{gov}$ | | -D | 0 |
| Bank Loans / mortgages | | -$BL_D$ | | | - $BL_{firms}$ | | - $BL_{gov}$ | | + BL | 0 |
| Bank equity | | | | | | | | | -$E_{bank}$ | 0 |
| Accounts receivable (bail out) | | | | | | | | | | |
| Bonds | | | + $B_{cons}$ | | | | - B | + $B_{repurchase}$ | + H - H | 0 |
| Shares | | | | + Shares | - Shares | | | | | 0 |
| Tangible capital | | | | | + $K_M$ | +$K_S$ | | | | + K |
| Net worth | - $NW_M$ | -$NW_D$ | - $NW_{LAB}$ | - $NW_{LABD}$ | -$NW_{Mfirm}$ | - $NW_{Sfirm}$ | - $NW_{Gov}$ | | 0 | - K |
| **Σ** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 |

*Table 1 Balance-sheet matrix*

Almost all flows are mutations between the deposits. In the Transactions-flow matrix (Table A2) the interactions between the flows (first column) and the stocks (deposits; first row) are summarized. Positive, incoming flows, such as wages increase the deposits of the respective deposit holders, for example consumers. Negative, outgoing flows decrease the deposits correspondingly. The most important mutations through in- and outgoing flows will be discussed below:

| Transactions-flow matrix | Consumers | | | | Firms | Firms | Government | Central | Bank(s) |
|---|---|---|---|---|---|---|---|---|---|
| | M-consumers | D-consumers | LAB-consumers | LABD-consumers | Manufacture | Services | | Bank | |
| | low income non-saving | low labour income inDebted | Labour / Assets / Bonds | Labour / Assets Shares /Dividend | | | | | |
| | | | ≈ Financial markets | | | | | | |
| Wages | $+W_m$ | $+W_D$ | $+W_{LB}$ | $+W_{LBC}$ | $-W_{firms\,M}$ | $-W_{firms\,S}$ | $-W_{gov}$ | | $-W_{banks}$ |
| Consumption | $-C_m$ | $-C_D$ | $-C_{LB}$ | $-C_{LBC}$ | $+C_M$ | $+C_S$ | | | |
| Investments | | | | | $+I_M$ $-I_M$ | $+I_S$ $-I_S$ | | | |
| | | | | | $+I_{M\,S}$ | $-I_{M\,S}$ | | | |
| Change in equities / shares | | | | $-\Delta E$ | $+\Delta E_{M+S}$ | | | | |
| Dividends | | | | $+Div$ | $-Div_{M+S}$ | | | | |
| Interest on deposits | | | $+\rho_d . D_{LAB}$ | $+\rho_d . D_{LABD}$ | | | $+\rho_d . D_{gov}$ | | $-\rho_d . D$ |
| Lending; loanable funds | | $+\Delta LF_D$ | $-0.5 . \Delta LF_D$ | $-0.5 . \Delta LF_D$ | | | | | |
| Interest on loanable funds | | $-\rho_l . LF_D$ | $+0.5 . \rho_l . LF_D$ | $+0.5 . \rho_l . LF_D$ | | | | | |
| Bank loans; money creation | | $+\Delta BL_D$ | | | $+\Delta BL_{firms}$ | | $+\Delta BL_{gov}$ | | 0 |
| Real asset transfers (housing) | | $-\Delta BL_D$ | $+0.5 . \Delta BL_D$ | $+0.5 . \Delta BL_D$ | | | | | |
| Interest on bank loans | | $-\rho_l . BL_D$ | | | $-\rho_l . BL_{firms}$ | | $-\rho_l . BL_{gov}$ | | $+\rho_l . BL$ |
| Repay Bank Loans /mortgages | | '$-\Delta BL_D/mt$ | | | $-\Delta BL_{firms}$ | | $-\Delta BL_{gov}$ | | 0 |
| Default on loans / mortgages | | $+f . BL_D$ | | | $+f . BL_{firms}$ | | | | $-f . BL$ |
| Recapitilization / bail out banks | | | | | | | $-f . BL$ | | $+f . BL$ |
| Bank equity capital requirement | | | | | | | | | $-\Delta E_{bank}$ |
| Government consumption | | | | | $+C_{gov\,M}$ | $+C_{gov\,S}$ | $-C_{gov}$ | | |
| Social Payments | + SP | | | | | | - SP | | |
| Taxation income profit / wealth | $-T_m$ | $-T_D$ | $-T_{LAB}$ | $-T_{LAD}$ | $-T_{firms}$ | | + T | | |
| Value Added Tax | - taxrate . $C_M$ | - taxrate . $C_D$ | - taxrate . $C_{LB}$ | - taxrate . $C_{LBC}$ | | | + taxrate . C | | |
| Change in governm. bonds | | | $-0.5\,\Delta B$ | $-0.5\,\Delta B$ | | | $+\Delta B$ | | |
| Interest on bonds | | | $+(\rho_l + 0.02) . B$ | | | | $-(\rho_l + 0.02) . B$ | | |
| Cental Bank bond purchase (QE) | | | $+\Delta B$ | | | | | $-\Delta B$ | |
| CB Money creation CBDC | | | | | | | + CBDC | -CBDC | |

*Table 2 Transactions-flow matrix*

## 3.1 Banks

Bank Loans $BL_{mc}$ are given (paid) by *banks* to consumers, firms and the government. In the process, money is created 'out of thin air' as debt by (simultaneous) elongation of both the asset and the liability side of the bank balance sheet (Werner 2014; 2016, p.361–379). The loan is repaid over the term of repayment as Bank loan repay $BL_{repay}$. On repayment the money will be 'destroyed' by writing off both sides of the asset and liability side of the borrower, deposit holder. In case of crisis, borrowers will default on their loans to an extent of $f.BL_{default}$, which implies a loss to the bank. Herein, f is the default fraction in module crisis mechanism. In case of bank resolution (by the government) the same amount is restored through recapitalization $f.BL_{recap}$ (Govrecap) of the bank(s), which might include as well nationalizations and other costs; part of the recapitalization is repaid to the government later (Figure 3.1).

The bank acquires interest paid over the Bank Loan $\rho.BL_{mc}$ from consumers (Consum BL interest), firms (Firms BL interest), government (Governm BL interest), and pays interest over the respective deposits $\rho.M_{dep}$ (Interest costs). Additional to interest Bank provision is acquired (over Consumer debt). Banks also receive income through intermediation of Loanable Funds (LF intermediation; existing money) . Losses in case of crisis $f.BL_{default}$ are compensated through recapitalization by the government $f.BL_{recap}$ (Govrecap). In that case the amount of Govrecap is transferred from the Government deposit to the Bank Reserve ('deposit') on the liability side of the balance sheet. This then compensates for the losses of unrecoverable bank loans at the asset side (Bad Debt Expense).

It is relevant to note, that the government achieves this recapitalization partly by means of existing money through raising taxation levels, partly through the emission of government bonds and partly through new bank loans. Bank income thus is given by

$$\rho\, BL_{mc} - \rho M_{dep} - f.BL_{default} + f.BL_{recap} + LF\ intermediation = \text{Bank income}$$

Bank income contributes to Bank wages and to Bank Equity, such that Bank Equity remains always higher than the Capital Requirement, which is the capital ratio (5%) of the outstanding debt to Firms and Consumers.

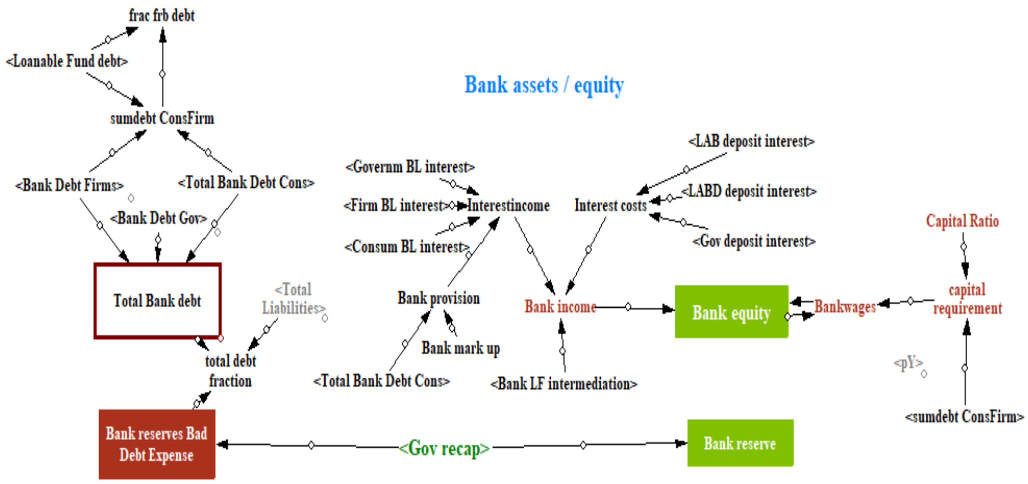



*Figure 3.1 Commercial banks in the balance sheet*

## 3.2 Firms

Firms pay wages to workers and receive money on their deposits by selling products to consumers and the government (Figure 3.2). Profits are calculated as sales revenues minus wage, interest and tax payments, and are paid out as dividend. Firms finance their investments in two ways:

- *Expansion investments* are made by selling *shares* ΔE (Share emissions) to the LABD-consumers, accounted for on their respective bank deposits. By means of the fraction firm bank loans, 35 % of the total expansion investments are expected to be primarily financed through bank loans, in particular to SME-firms, with a repay term of 10 years.
- Replacement investments (€Investdepr) to compensate for capital depreciation (δ p K) are financed from *retained earnings*, drawn from bank deposits of firms (existing money). To this end, an appropriate part of the profits is maintained on these deposits as retained earnings and is via 'Firm liquidity' not 'liquid' and not available as dividend to the LABD-consumers.

Firms transaction flows are summarized as:

$$C + I_{in} + \Delta E + \Delta BL_{firms} = W_{firms} + I_{out} + Div + \rho_l\, BL_{firms} + T_{firms} + \Delta BL_{repay} \qquad (17)$$

Income (at the left hand side of the equation) is derived from selling goods and services to consumers and government C, selling of investment goods to other firms $I_{in}$, shares emission ΔE and obtained Bank Loans $\Delta BL_{firms}$. In the Vensim sheet the variables at the input side are indicated as:
Consumption + Governm consumption + €Investment + Share emissions + Bank loan firms
(no deposit interest, as the money is 'used' for depreciation investments; retained earnings)

Expenditures (right hand side) are wages W, dividend on shares Div, interest on bank loans ρ.BL, Taxes T and repayment of bank loans $\Delta BL_{repay}$. Investments $I_{out}$ are the costs of investments which are purchased from other firms. For the production sector as a whole, therefore, the 'consumed' investments $I_{out}$ and produced investments $I_{in}$ cancel each other out.
In the Vensim sheet, these expenditures are labelled correspondingly:

Total Firm wages MS + €Investment + Dividend + Firm interest + Firm taxation + Bank loan repay firm.

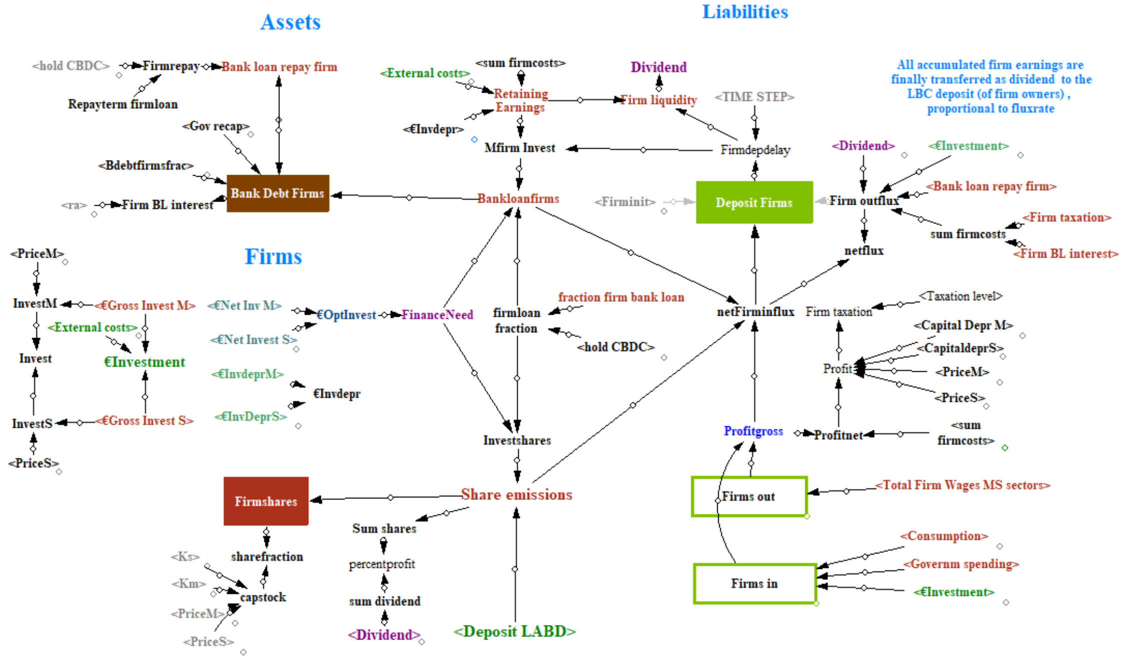



*Figure 3.2 Firms*

## 3.3 Households / Consumers

The four categories of consumers receive income from labour in the form of wages and pay income taxes and VAT. The M (Minimum-) consumers have no debt, but neither a significant bank deposit. The receive Wages M and Social Payments (see government) and pay for M consumption and Taxation M consumers.

Only the category of D-consumers has debts, both as bank loans (newly created money) and as Loanable funds (Bank intermediated existing money of LAB and LABD-deposits) . The net D-income equals wage income minus taxation, minus interest dependent costs of housing (repay and interest costs of mortgages and loanable funds). The remaining income is assumed to be entirely spent on consumption (Figure 3.3).

D-consumer transactions thus are given by:

$$W_D \; = \; C_D + \rho_a \, LF_D \; + \rho_a \, BL_D + {}^{BL_D}/_{maturity} + T \qquad (18)$$

with W wages, C consumption, $\rho_a$ LF and $\rho_a$BL the interest payments on Loanable Funds and Bank Loans, ΔBL/maturity the yearly repay on the Bank Loan (mortgage) and T taxation.
In the model sheet these variables are denoted as:
Wages D = D consumption + Loan funds interest + Repay Interest fraction.

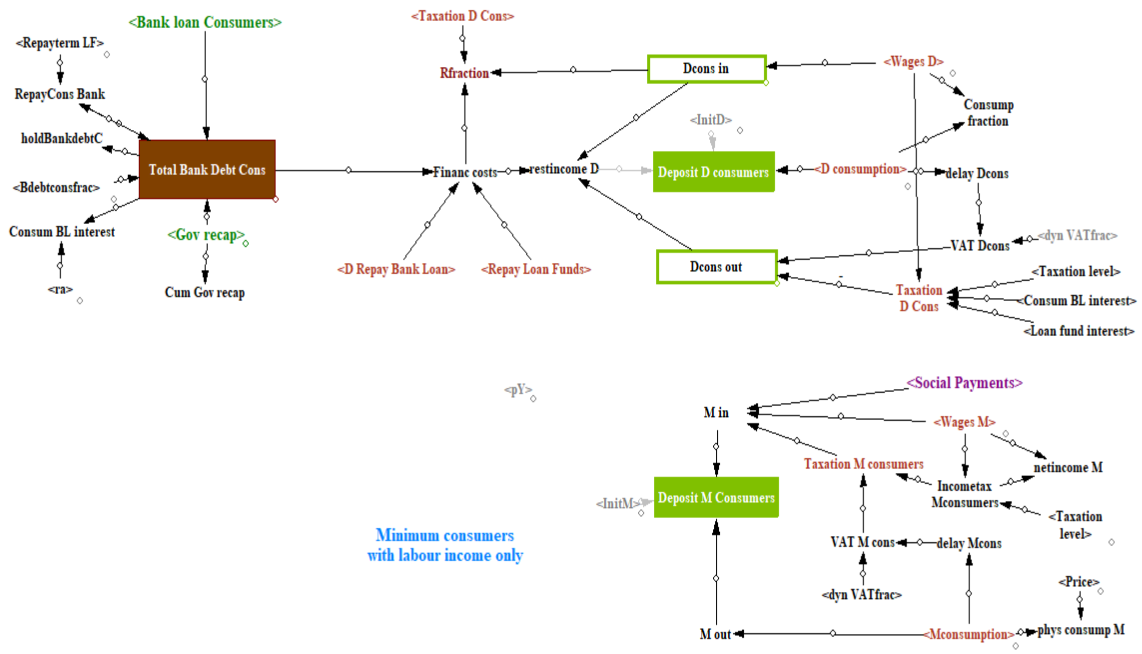



*Figure 3.3 Debt-bearing D- and Minimum M-consumers*

The other two consumer categories have a positive bank deposit and no loans. They invest in Bonds (LAB and LABD-consumers) and in equity / shares in firms, thus receiving Dividend (LABD-consumers). LAD / LABD-consumer transaction-flows are given by:

$$W_{LABD} + \rho_l D_{LAB} + \Delta BFL_{asset} + \rho_b B_{LAB} + div_{LABD} = C_{LABD} + \Delta B_{LAB} + \Delta E_{LABD} + T \qquad (19)$$

with W wages, $\rho_l D_{LAB}$ the LAB deposit interest, $\Delta BFL_{asset}$ the yield of sold (real) assets, ρ B the interest received from bonds and dividend from shares. C consumption, ΔB the costs of acquired government bonds (LAB-consumers), ΔE the costs of acquired shares (LABD) and T taxation. In the model scheme this is represented for both LAB and LABD by the following variables:
Wages LAB + LAB deposit interest + Sold asset LAB + Maturing Bonds LAB (repay and interest) + Dividend LABD (only) = LAB consumption + Bond purchase LAB + (purchased) Share emissions (LABD not in LAB) + Taxation (income, wealth, VAT).

In the model, $\Delta BFL_{asset}$ is the bank loan (mortgage) though which asset / houses are bought from the asset-owning LAB and LABD consumers. These loans are directly transferred from the bank to the sellers of the assets, thus to the LAB and LABD deposits. The same holds for bank intermediated loanable funds. Here existing money of LAB / LABD-consumers is lend to D-consumers, but here also the money is directly transferred to the previous owners, which were LAB / LABD-consumers as well. The money thus remains within these consumer categories and no net transfer takes place. The repayments of the loans are transferred from the lending D-consumer deposits to the LAB / LABD-deposits as D repay LF to LAB / LABD (Figure 3.4).

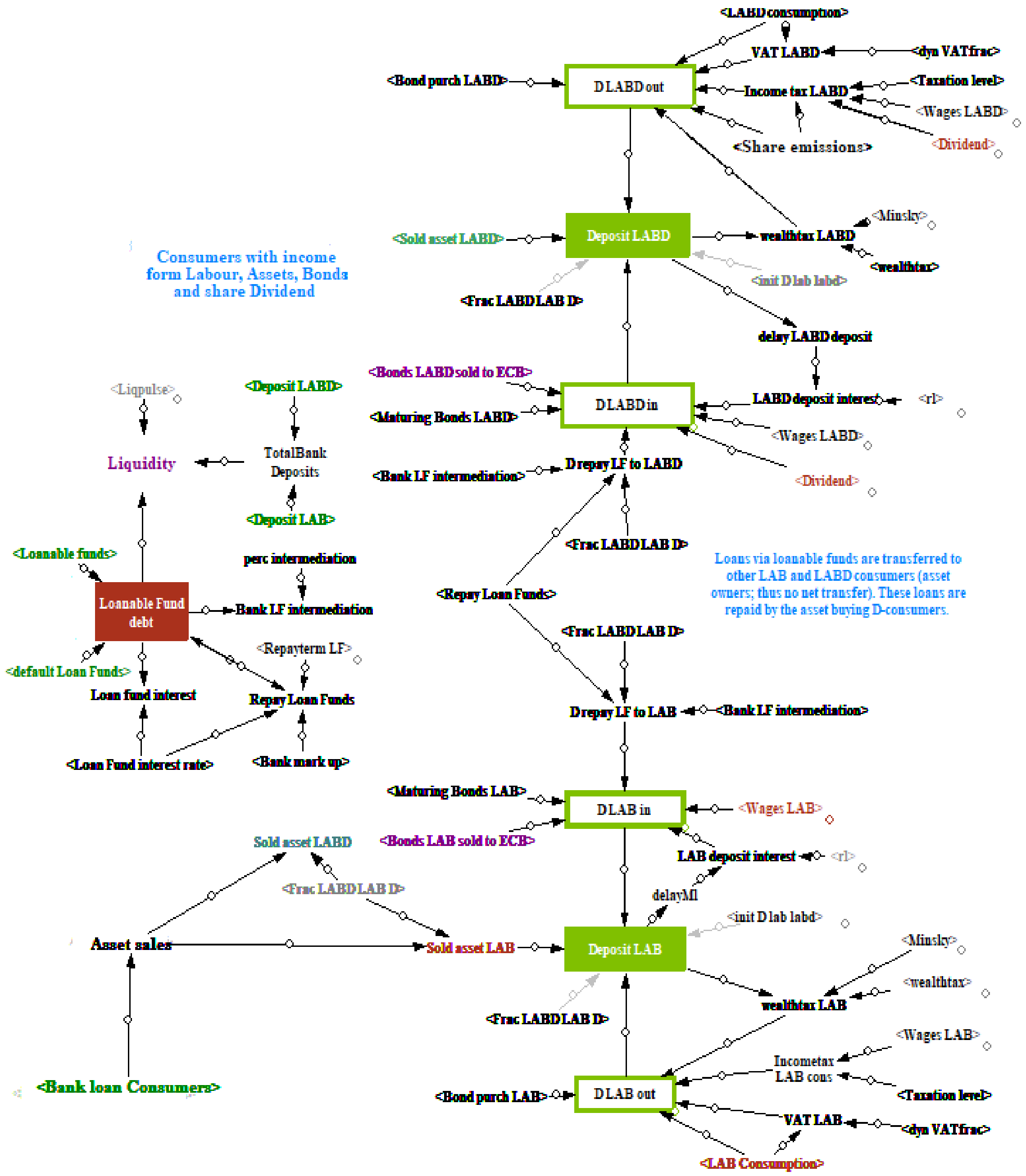



*Figure 3.4 LABD and LAB-consumers*

In the Quantitative Easing (QE) program of the ECB, bonds were purchased by the ECB from the 'financial markets' which are represented in the model by the LAB and LABD deposits. The objective was to bring more liquidity in the financial system in order to increase the too low inflation level to the 2%-target. In the module on Government Bonds Emissions, this purchase program is modelled as a direct transfer of money from the ECB to the LAB and LABD deposits (omitting the intermediate step of commercial banks). The transfers are labelled as Bonds LABD (LAB) sold to ECB.

## 3.4 Consumption

Following Godley and Lavoie (2007), consumption of the LAB- and LAD-consumers is assumed to depend on both income  and wealth level: :

$$C = a + b_i \,.\, F_{net} + b_w \,.\, M_{liq\ ass} \qquad \text{(M/yr)} \qquad (20)$$

where C is consumption, a is a constant, $F_{net}$ is the net income, $M_{liq\ ass}$ represents the net liquid assets on the respective LAB- and LAD-deposits. $b_i$ and $b_w$ are the propensities to consume for income and wealth. Net income $F_{net}$ consists of the wages, of interests on deposits and loans, of interest on bonds and of dividends minus taxation (Figure 3.5).

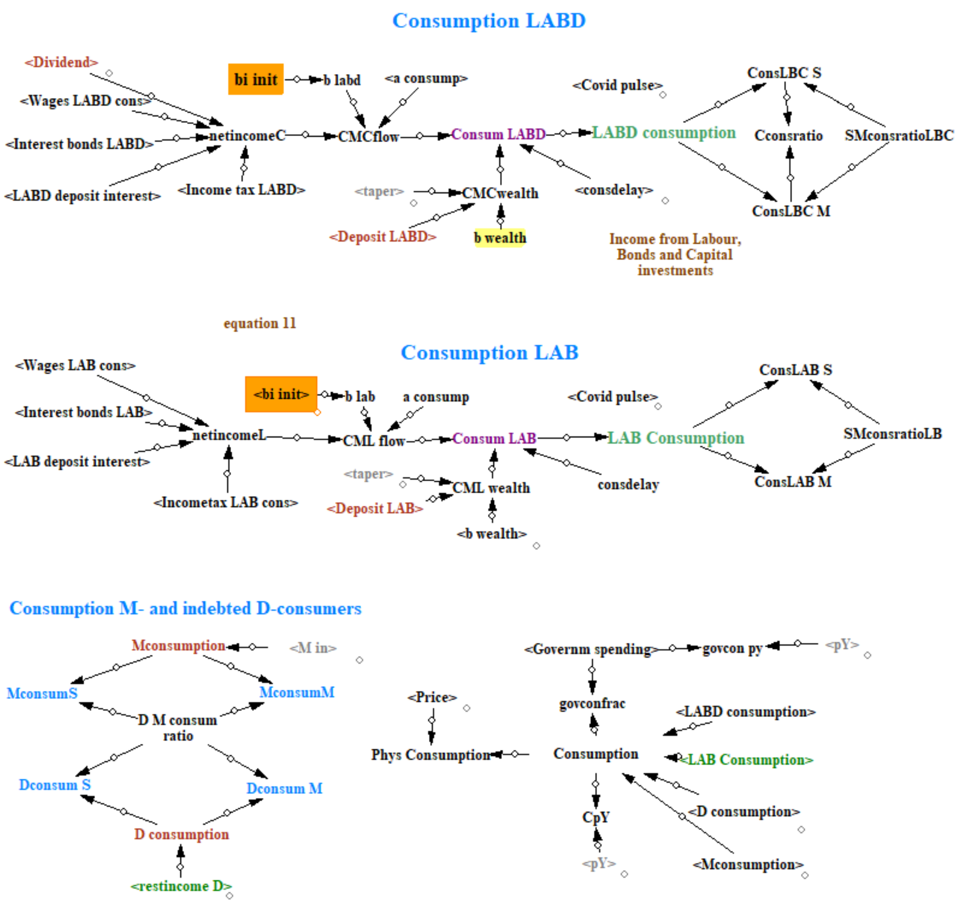



*Figure 3.5 Consumption*

In the Consumption modules, this is represented as  (Figure 19):
LAB / LABD consumption =  a consump + b init + b wealth . LAB / LABD  deposit.

Parameter values are derived from literature and model experiments. From statistical analyses, the propensity to consume out of wealth ($b_w$) is found to vary between 0.01 and 0.05 (Lustig et al., 2013) and has been set at 0.01, with the option to increase the wealth taxation over a chosen period to 0.03 (3%). The propensity to consume for income $b_i$ is set at 0.8. (The value of a is arbitrarily set at ‘10’ for reasons of numerical stability only.)

The D consumption is computed as income of the D consumers minus costs:
D consumption = Wages D – D repay Bank Loan – Repay Loanable funds – Taxation D consumers– fixed minimum deposit level.

M consumption is given correspondingly by:
M consumption = Wages M + Social Payments – Taxation M consumers.

## 3.5 Government

Government is financed by the sum of taxation (T), Bonds emission $B_{emitted}$, Bank Loans Gov $\Delta BL_{gov}$ and money creation $MC_{gov}$. The taxes are raised on the basis of gross consumer/worker wages and on net profit of firms i.e. after dividend payments. Besides, a Value Added Tax is applied on the consumption flow; Figure 3.6.
Government expenses are given by the sum of Wages (Wages Gov sector), Government consumption $C_{gov}$ , Social payments, the interest and repay on Bonds (ρ B) (Maturing Bonds) and Bank loans (ρ BL; Repay gov bank loan).

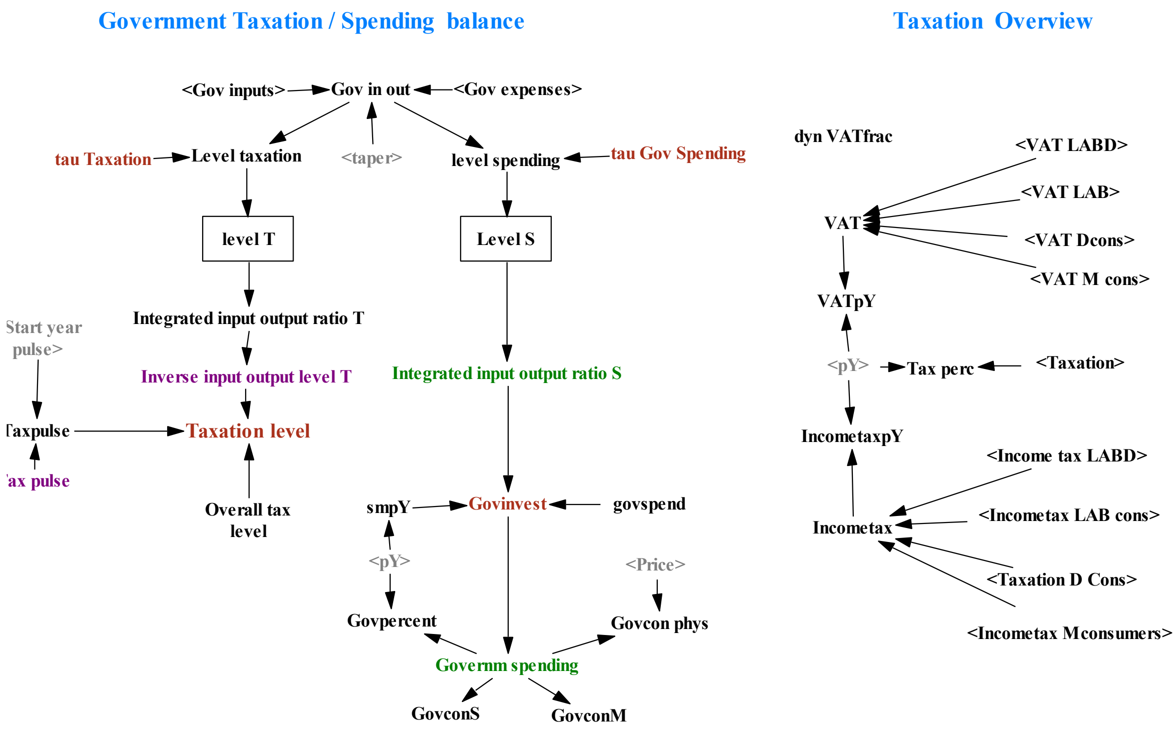



*Figure 3.6 Taxation and government spending*

Social payments are derived as the level of unemployment x govern. input / output balance (gov in out) in the module Government Taxation / Spending balance (Figure 3.6). As a consequence, government social benefits increase when unemployment rises, and decrease in case of government deficits.
In case of financial crisis, government is expected to recapitalize commercial banks for a certain fraction f of their total outstanding bank loan BL. Accordingly, government debt will increase with the amount $f.BL_{recap}$ (Gov recap) The overall government income and spending thus is given by:

$$T + B_{emitted} + \Delta\, BL_{gov} + MC_{gov} = W_{gov} + C_{gov} + SocPay + \rho_b\, .B + \rho_{bl}\, .BL_{gov} + f.BL_{recap} \qquad (21)$$

In the module Government Taxation / Spending balance, the ratio between the input and output (income and expenses) of government finance is integrated over time by Level T and Level S. Both levels thus fluctuate around '1', reflecting the periods of a positive and negative financial balance. The required taxation level is subsequently derived from 1/ Level T (Inverse input output level T), which implies higher taxation when the inputs fall short of the outputs.
Correspondingly, but eventually with a different time constant tau Gov Spending, the level of government spending (Govinvest) is derived as proportional to Level S, which implies higher spending when the inputs are higher than the outputs.

## Government debt

The overall governmental finance is constrained and controlled by two factors:

- Imbalances in government income versus spending in the first place are accommodated by taxation adjustments. Overall government debt tends to the 60 % EU-regulation. In case this level is reached, taxation is increased further.
- In case the actual debt is lower than 60 % there apparently is room for a further increase in government debt. Assuming that this room in general will be leveraged, government liquidity is increased by the issuance of bonds (90 %) and increasing loans from private banks (10 %). As a consequence, in the model the real government debt will stay within the 'EU-allowed' level of government debt. However, in reality the average government debt in the Eurozone just before the 2008-crisis was about 70 %, increasing with about 20% to over 90 % after the crisis, as shown in Figure 3.7 (lower left). As this is broadly in line with the levels of increase observed during the 2008 financial crisis, it is concluded that the default fraction (of 10% of debt) in Figure 2.11 is appropriate.
- In case of financial crisis, when governments have to come to the rescue of defaulting commercial banks, modelled government debt is allowed to increase with the amount of $f.BL_{recap}$ over the 60 %-level. In the following years, the debts is gradually forced back to the 60 %-level. The fraction f is estimated from the empirical, observed increase of government debt during financial crisis (2008).

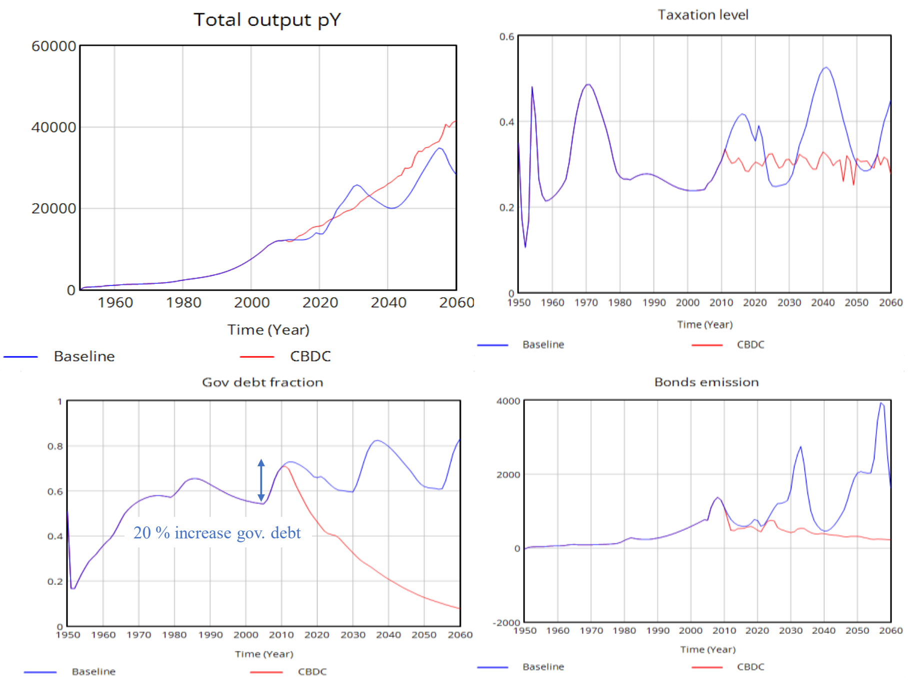



*Figure 3.7 Example model outputs for Government; baseline and CBDC*

In Figure 3.7 example outputs are given for total production, bonds- emission, taxation and in particular the Government Debt Fraction. Corresponding to the EU-regulations, the debt fraction should not exceed the 60%-level. During Minsky episodes, and subsequently provoked recapitalisation of banks by the government, the required substantial amount of money is again borrowed on the financial markets. This gives rise to increasing debt levels.

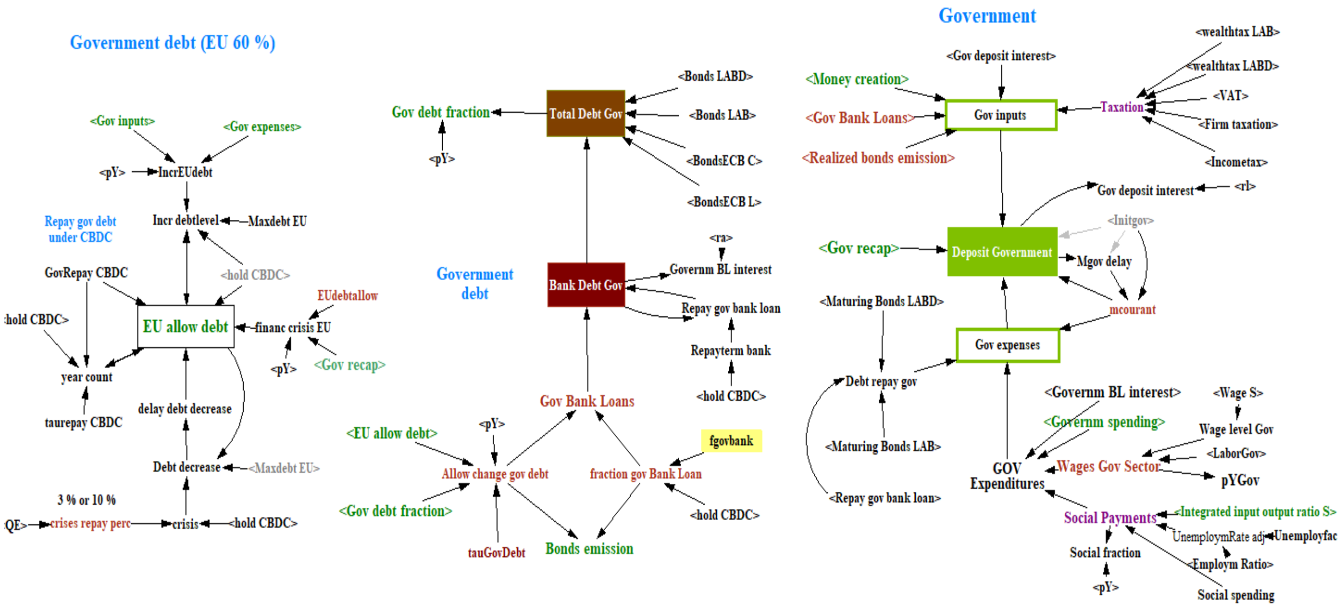



*Figure 3.8 Government debt and deposit (liability side balance sheet)*

In the Government debt (60%) module, the 60 % EU maximum debt level is represented by the EU allowable debt level (Figure3.8 left). In case the EU debtallow entry is set to '1', a higher debt level is allowed temporarily, in particular during financial crises. In that case a temporarily higher level will be allowed, which corresponds to the amount of the government recapitalization of banks (Gov recap). The debt level > 60 % is subsequently reduced according to the crisis repay percentage. In case of ECB-QE (QE=1) this percentage equals 10 %, otherwise 3%.
The allowable change in government debt (positive or negative) is computed as the difference between the EU allow debt level and the actual government debt level (given by the gov debt fraction). The change in debt is allocated to Bank Loans Government versus Bonds emissions according to the fraction government Bank loan (Figure 23.8). The consequences of the changes in the debt position become manifest through the Gov inputs and the Gov expenses. An eventually too much distorted balance is restored through the above discussed Taxation- Government Spending mechanism.

In case of fully centralized ECB-money creation (CBDC=1) the government debt $BL_{gov}$ can be repaid without any consequence, as the repaid money is nullified by the commercial bank. In that case the debt can be reduced with a constant factor every year (year count). The EU allowable debt will show a strong decrease. The government debt will be repaid through additional money creation, while maintaining the exact inflation target level of 2 %.

The Bonds-emission, which was the result of handling government debt is the left hand side entry for the handling of bonds (in Figure 3.9). The upper and lower half of the Figure refer to the LABD- and LAB- consumers / deposit holders. From the central (box-shaped 'levels' / stocks) the bonds LABD level changes over time given the maturing of bonds and the repurchase program of the ECB. Via commercial banks, ECB created money for these QE-repurchase programs. The Bonds LABD-level is reduced by the Bonds LABD sold to ECB.

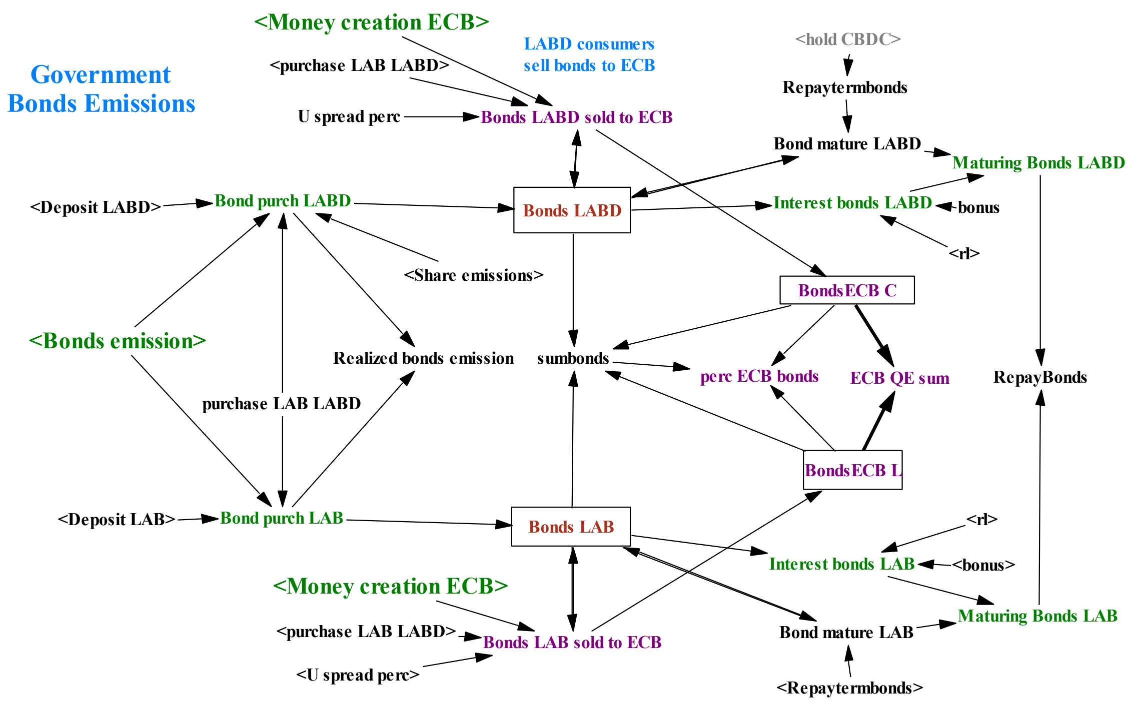



*Figure 3.9 Emission of government bonds and QE- repurchase by ECB*

## 3.6 European Central Bank; monetary policies

### Quantitative Easing

This buyback of ECB government (and corporate) bonds on the financial markets in the period 2012–2022 (LAB and LABD deposits) was intended to increase liquidity in the euro area system and thereby bring inflation that was too low to the target level of 2%. The amount of created ECB money (as a historical fact) is an exogenous input to the model via two ECB-programmes: the (general Asset Purchase Program and the later Pandemic Emergency Purchase Program (Figure 3.10). In case QE=1 (Dashboard and ECB) this directly results in Money creation ECB (Figure 23). In case QE=0 (no Quantitative Easing), the model reconstructs the historical record without this ECB intervention.
In the adjacent module Government Bond Emissions, bonds are repurchased from Bonds LABD- and Bonds LAB to the available amount Money creation ECB. Given purchase LAB LABD =0.5, ECB purchases bonds in equal amounts.

Just as for many other parameters, the model can be run in the stationary mode (Stationary model = 1, see below). In this mode a QE pulse can be given (f .e. 25) in a Start year QE pulse, in order to study the model response to a single, isolated, temporary increase of the ECB money creation (Figure 3.10).

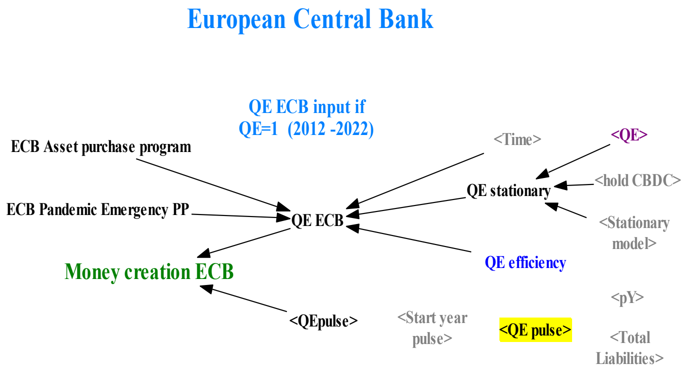



*Figure 3.10 ECB; historical Quantitative Easing money creation*

The effect of the ECB QE-Additional Purchase Program (APP) is shown in Figure3.11. Without the QE-APP indeed a string deflation would have occurred (according to the model; red lines in Figure 3,11). This in particular is demonstrated by the total (monetary) output and the inflation level. The levels of the physical production and employment rate are less affected on the shorter term, but strongly on the longer term.

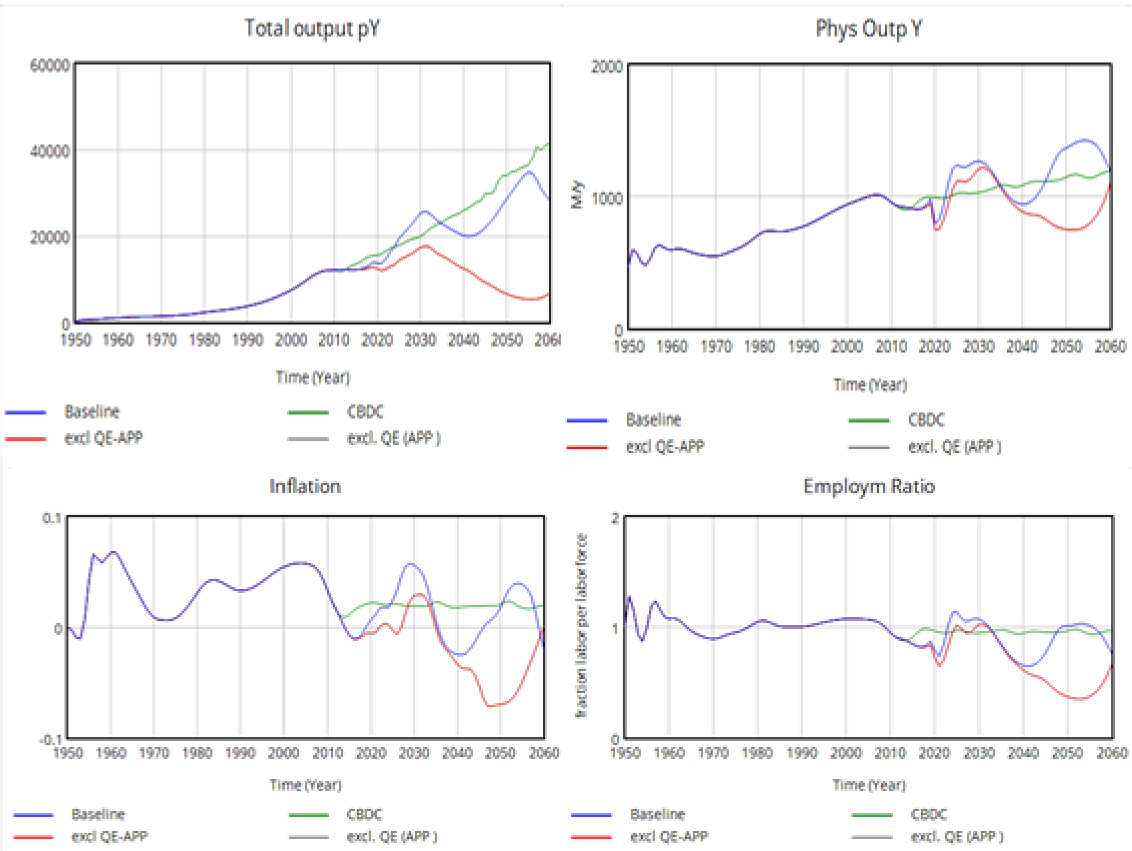



*Figure 3.11 Computations for the Baseline (blue), excluding ECB-Quantitative Easing APP and CBDC (starting 2010)*

## CBDC money creation

In the model (Money creation CBDC), money is created by commercial banks eqn. 15), by ECB or by both (Figure 3.12). Money created by the ECB can take the form of Central Bank Digital Currency (CBDC) or, when the ECB creates it alongside money creation by commercial banks, as Central Bank Created Currency (CBCC). In the latter case, the ECB created money also can be CBDC.
In the model simulations of the respective policy alternatives, Money creation $MC_{CB}$ by ECB is directed to maintain the inflation rate dp/p around the inflation target [dp/p] $_{target}$ (2 %):

If dp/p < dp/p $_{target}$:
$$MC_{CB} = -\left( {}^{dp}/_{p} - {}^{dp}/_{p\ target} \right) \cdot F_{MC\ CB} \qquad (€/year) \quad (22)$$

Herein, $F_{MC\ CB}$ is the multiplier dp/p . pY (inflation target x overall monetary production; Infl target pY) to adjust money creation and interest rate increase to achieve optimal price stability.

In the Money creation module, the computation starts from the actual overall Price, as weighted sum of the M- and S- sector prices. Under conventional conditions (without ECB-money creation) level Price target follows the actual Price. After the hypothetical transition to ECB-money creation, Price target develops over time conform the inflation target. A weighted combination of the difference between this target function and the actual price level (Target min Price) and the first derivative of this difference (TminP 1$^{st}$ deriv) gives the Price discrepancy. Together with the Infl target pY, this give the Liquidity discrepancy, which, in case CBDC or CBCC =1, results in Money creation.

The created money $MC_{gov}$ is channelled to the real economy via the Gov inputs to the Deposit Government. As a result in the module Government Taxation / Spending the financial balance Gov inputs / Gov expenses = Gov in out will increase. As discussed above, the taxation / spending mechanism then will lower taxation and increase government spending, according to the values of tau Taxation and tau Spending. It goes without saying that other ratio's between reduced taxation and increased government spending can be chosen.

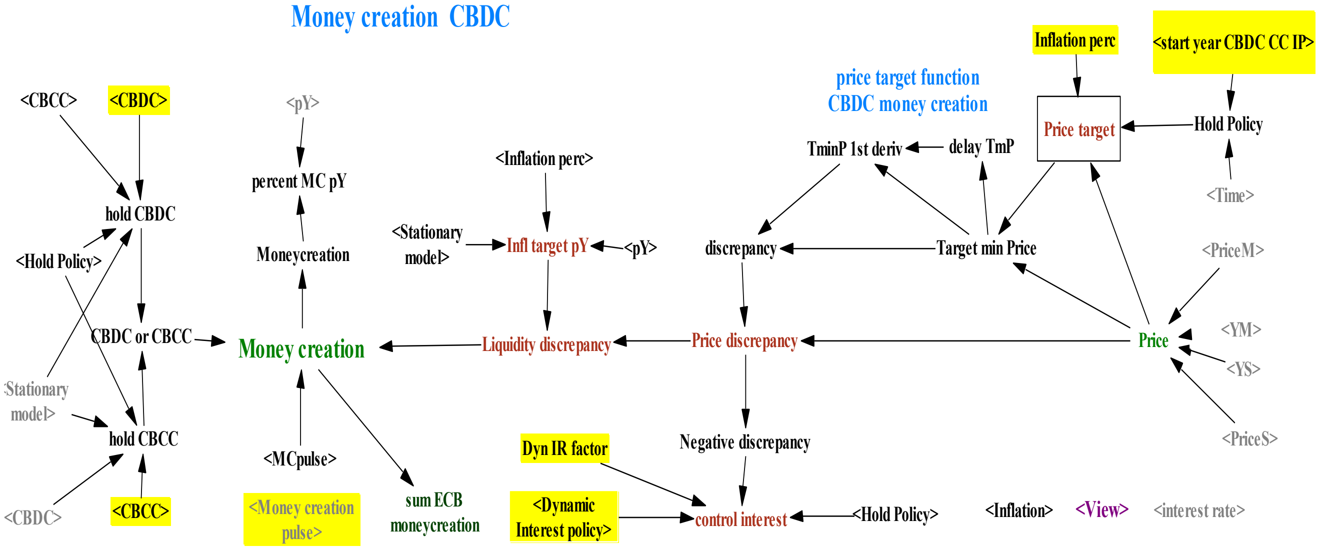



*Figure 3.12 ECB-CBDC money creation*

### Interest rate policy

In the recent ECB program on Qualitative Easing (QE) inflation initially was too low, which (thus) resulted in ECB-money creation via the large scale purchase of bonds from the financial markets (LAB and LABD-deposits) as discussed above. After 2022, inflation became too high, after which the overall economy was 'cooled down' by means of increase of the policy interest rate. The dynamic increase $d\ P_{ir}$ of the interest rate as applied in eqn.10 thus is modelled as;

If dp/p > dp/p $_{target}$ : $$d\ P_{ir} = \left( {}^{dp}/_{p} - {}^{dp}/_{p\ target} \right) \cdot F_{Pir} \qquad (\text{€/year}) \qquad (23)$$

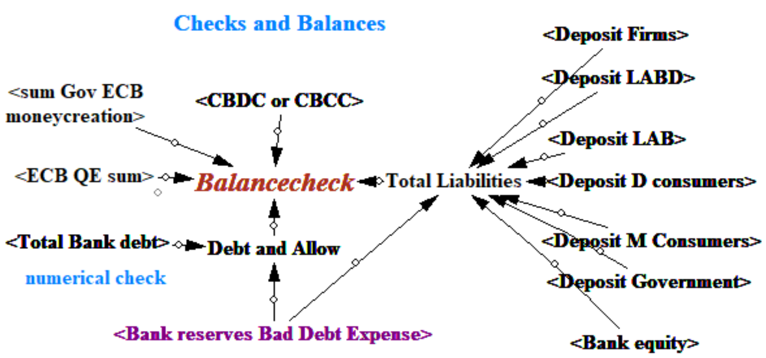
Herein $F_{Pir}$ is $F_{MC\ CB}$ times a scalable reduction factor Dyn IR factor =0.01

This policy can be activated via Interest policy (=1) on Dashboard and in Money creation) or in combination with CBDC (=1) or CBCC (=1). Any combination of these policies can be chosen.
In the model this Interest Policy is simulated by dynamically increasing the *natural* interest rate, as computed in the Interest rate module, with an additional control interest. This level is derived from the earlier mentioned Price discrepancy, such that control interest is positive (higher policy interest rate) in case Target min Price is negative, In that case the actual price level is higher than the target price, which implies too much inflation. At the now higher interest rate, investments will decrease and finally the overall price level will decrease.

## 4 Checks and Balances

The balance sheet matrix is shown in Table 1 is continuously evaluated by means of a Balance check. At the upper right hand side of the model sheet, the overall check of the Financial system is made in the *Balance check* (Figure 4.1). Herein the total amount of money in the system, on the liability side of the overall bank balance sheet, is checked against the creation of this money by means of Bank Loans, ECB money creation and the ECB-QE-program. The Bank reserves Bad Debt Expense is the provision of lost outstanding bank debt on the Asset side, which is compensated by government recapitalization through Bank reserves on the Liability side of the balance sheet. Because the balance check remains constant throughout the modelling period, the model is confirmed to be stock-flow consistent.

In the same module, the consistency of the economic side of the model is checked for the Market sector ( pYcheck) and the overall system (pYcheck MSG). In both case the normalized Wages and the Profits are checked against the Consumption and the Investments; both checks have to be (near) zero. Accounting for the small numerical discrepancies in the model (delays etc) it is concluded that Wages + Profits = Consumption + Investment.



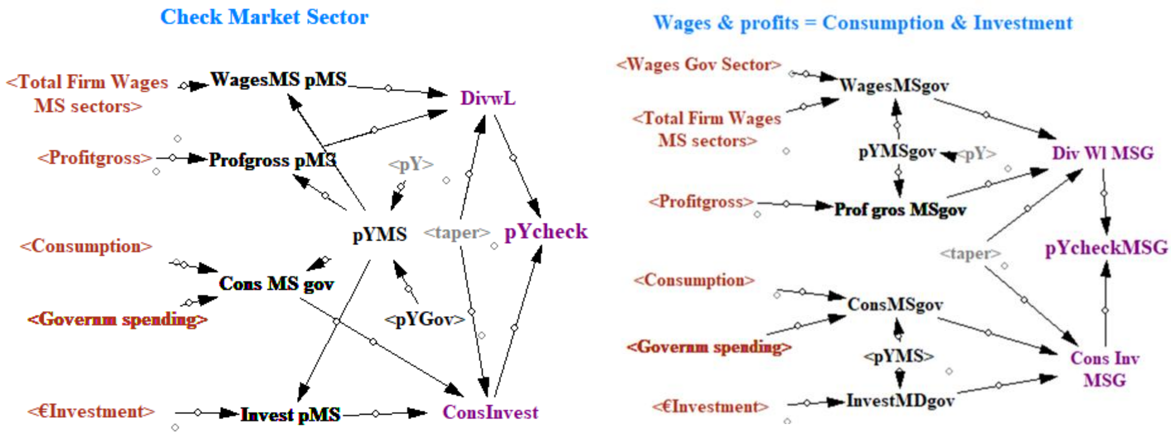



*Figure 4.1  Checks and balances*

## 5 Piketty's r and g

Figure 28 plots share profits r against  economic growth g. The French economist Piketty has pointed to the fact that r structurally exceeds g, with consequences for the accumulation of wealth in the respective sections of society. With regard to eqn. 3, the net profit (shares) is part of the gross profit, which also includes the other cost of capital (bank loans, etc.):
Gross profit =  net profit (share profit) + financial costs of the company (bank loans, etc.).
Gross profit is given by the fraction α (alpha) in equation 1, as shown in Figure 2.3. This share is (therefore) steadily increasing and is currently modelled around 0.4. This means that 40% of total production GDP goes to capital and 60% to labour power.

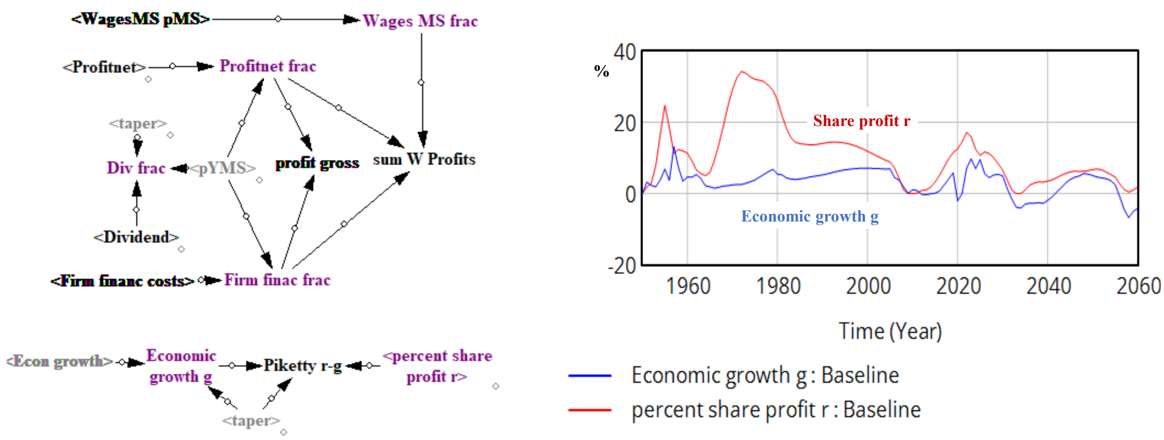



*Figure 5.1 Comparison of capital (share) profits r versus economic growth g.*

## 6 Wealth development

Given the pronounced differences in pay, the distribution and evolution of wealth may be relevant when considering the impact of different policy measures. The Checks and Balances section of the model sheet (top right) estimates the wealth development per household; Figure 28. In this, the assets are calculated as the sum of the respective deposits, the value of final bonds and shares. The total value of the home per household is estimated;

- for the D-consumers as the value of the house minus the remaining bank debt.
- for the LAB and LABD consumers as already included in the respective deposits. In the model, the money that is newly created in mortgage lending is transferred directly to these two consumer categories. This allows these households to be considered as having already sold their homes to the D-consumers, so that the value of these homes is already included in their deposits.

The results of these estimates are shown in Figure 6.1.

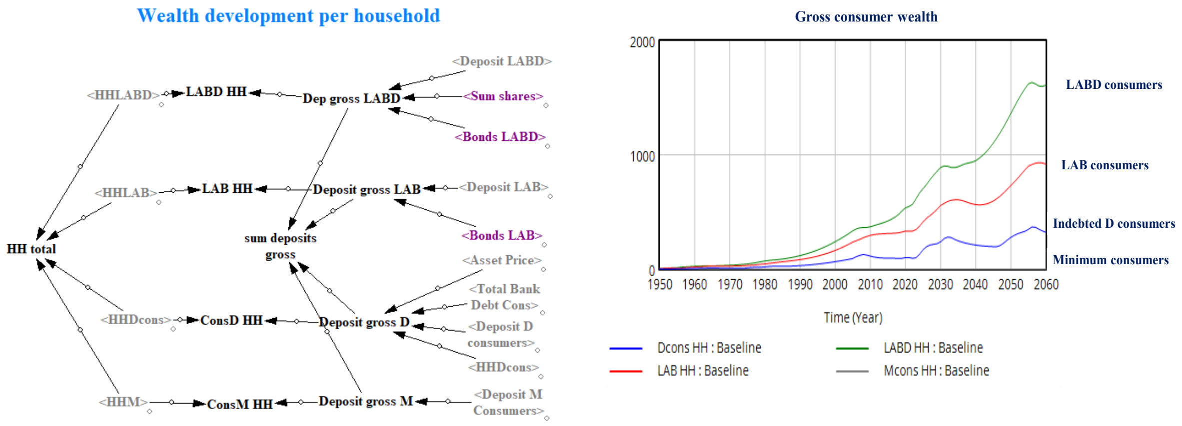



*Figure 6.1 Wealth development per household*

## 7 Stationary model

Quality control is an important topic, both with regard to:

- the development and operation of the model system in the numerical sense, and if satisfactory,
- the originally intended interpretation and understanding of the rather complex dynamic interactions in the financial-economic system.

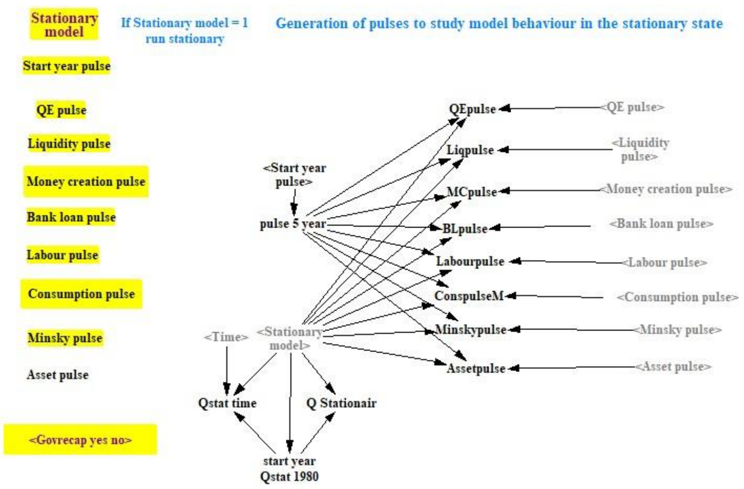



*Figure 7.1 Dashboard for numerical experiments under stationary conditions*

To serve both purposes, the model can be simply transferred to the stationary state, in which as many parameters as possible, such as regular labour capacity, total factor productivity (equation 1), labour capital substitution (α) and so on, are kept constant, in order to be able to assess the effects of controlled, relevant changes. This implies, for example, that money creation still takes place in stationary mode. Nevertheless, the system is so stable that the many system responses to isolated and well-defined changes (pulse, step functions) can be interpreted. Setting " stationary model" in the dashboard to "1" will put the model in stationary mode (Figure 7.1). The pulse, with a duration of 5 or 10 years (in pulse 5 years), starts at the 'Start year pulse'.


*Figure 7.2 Example results for the model in stationary mode with a QE-pulse in 2010.*

In the example of Figure 7.2, a Labour pulse of 75 is given. By first running the model in the *Baseline* (to be entered as a name in the horizontal top bar of the model sheet) as a stationary version, with Labour pulse =0 and then with Labour pulse = 75 under a different file name (e.g. *Labour 75*'), the effects of the Labour pulse on all other model parameters are easy to see.
In this example, an increase in labour leads to higher production/physical output Y and lower wage levels of MS, which then leads to a decrease in the price level.

## 8 Model calibration

The aim of the model is to improve the understanding of overall macroeconomic developments in interaction with the financial system.
To this end, the best possible reconstruction of the 'true' developments is measured, as provided by statistical data of the main macroeconomic parameters, in particular total GDP output, total liabilities, inflation, interest and debt. If such a reconstruction can reasonably be made, meaningful extrapolations to the future can be made, based on various assumptions and scenarios.

The historical reconstruction is based on a number of (well-known) economic mechanisms discussed above, such as the production functions, interest rates, dynamic behaviour of asset/house prices and money creation. Within a limited range, the respective parameters that drive these mechanisms can be adjusted to best adapt the model results to the statistical data. However, the number of parameters that can be adjusted is large compared to the available statistical data. This problem is partly solved by connecting these respective mechanisms whenever possible. For example, the asset price is linked to the net income of D consumers who have mortgage debt. This net profit is derived from the total economic production pY. At the same time, mortgages for assets are largely created by money creation by private banks. This affects liquidity, interest rates, investments and thus again the total production pJ. Such reductions in the number of independent variables facilitate the 'alignment' of the model with the data.

In fitting the model to the empirical statistical data, the following steps can be distinguished:

1 Consumption as given by $C = a + b_i \cdot F_{net}$ (excl wealth consumption) in eqn. 20 (Figure 3.5), in particular the coefficient $b_i$ which is the fraction of net income F to be spend on consumption, determines the ratio between investment, thus total income pY, and savings. This translates in the ratio between pY and total liabilities (M3-money in the system). Given the identity pY=Mv, the velocity v at which money circulates through the economy is given by v = pY / total liabilities. The coefficient $b_i$ is to be chosen such that the modelled velocity equals the velocity which is given by the statistical data. This resulted in the value $b_i = 0.77$. As shown in Figure 9.1 (lower left) the modelled and the observed velocities then are in very good agreement.

2 The (natural) interest rate ρ, as given in eqn. 10, is the second important factor in the overall model performance, in particular the weighting factor $d_{supply}$, which determines how strong the interest rate responses to increasing liquidity. As liquidity (and total liabilities) gradually increase over time, the interest rate will show a decreasing trend. According to eqn. 5, lower interest rates will increase investment and thus finally pY. Increasing values of $d_{supply}$ thus result in increasing values of total production pY.

3 The Loanable Fund fraction $F_{loanf}$ as given in eqn.14 and Figure 2.8, determines the fraction of required bank intermediated loans which are acquired as existing money, rather than money which is newly created. This existing money originates from the deposits of the LABD and LAB-consumers, which represent 'financial markets'. Higher values of $F_{loanf}$ thus will result in less creation of new money, thus less increase in the amount of M3-money / total liabilities. This implies less liquidity, thus higher interest rates, less investments, less capital, thus less production pY. As $F_{loanf}$ depends on the increase of liquidity, more existing money will be used and less money will be created for lending in case of increasing liquidity levels, such as for example during strong inflow of liquidity through QE.
A second relevant (adjustment) variable for bank loans is the End High LF banking regime. It indicates the year in which the banking system gradually transitioned from peer-to-peer (loanable funds) lending to lending through new money creation. After this year (set for 1970), the *loanable fund ratio* fell to a lower level (about 6%), resulting in fewer peer-to-peer loans and increasing money creation.

4 Although also less relevant, the same reasoning holds for the extent to which government and firms acquire loans (Govbankloan and Bankloanfirms) via bank loans or via bonds, respectively shares. In case of bank loans the money is newly created and total liabilities as well as liquidity thus will increase. The fraction of the loan which is required as bank loan for the government is fgovbank (Figure 3.8) and firmbankloan for firms (Figure 3.2).

5 Given the important role of the asset (boom-bust) cycle in the model, the model has to be initialized with respect to the first cycle. This then determines the later successive Minsky moments. To this end, a short pulse in the Ability to Pay has to be given in the initialization period of the model (thus before 1980). As the financial crisis occurred in 2008 and given the inherent nature of the asset price cycle, this pulseAtP was given in1974 (Figure 2.6). It thus marks the beginning of increasing liquidity, and thus the business cycle.

# 9 Overall Model results

Finally, Figure 9.1 shows the model results for the important variables Total Production, Total Liabilities, Velocity, Asset price and natural Interest rate and Inflation, compared to statistical data (red dotted lines). For Total Production and Total Liabilities, the model results are fairly consistent with the observations. For inflation and interest rates, the absolute levels deviate, but the dynamic behaviour is reasonably reproduced.

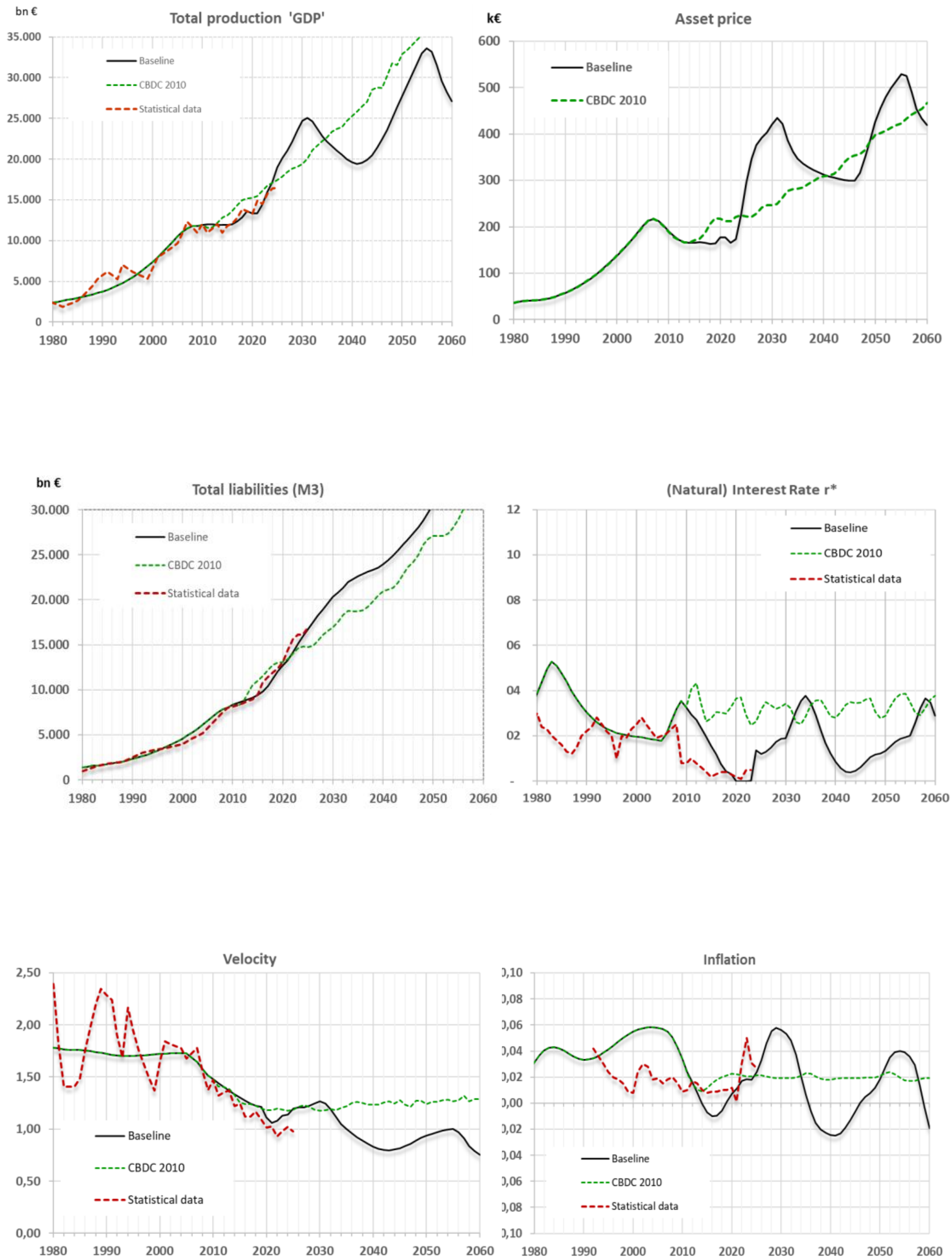



*Figure 9.1 Example model output for Baseline and CBDC and comparison with statistical data.*

## CBDC; digital euro

The green dotted lines in Figure 9.1 show the results for the hypothetical case of 100% adoption of the digital euro in 2010, immediately after the 2008 financial crisis. The stability of the system will then increase considerably due to the transition from the current procyclical to an inherently anticyclical system in which the money is exclusively created by the ECB and thus directed to system-stability only. The target inflation level of 2% can be maintained until the end of the modelling period and financial and economic crises no longer occur.

## Explaining system-behaviour from applied policies

Given the rather precise fit between the model results and the statistical data, the developments of total production and total liabilities (M3-money) can be understood from applied policies (Figure 9.2):

1. During the initial period between 1950 and 1980, a reasonable fit between modelled and statistical data was only achieved by assuming a far lower level of money creation, thus a much higher fraction of existing money in bank lending ($F_{loanf}$ > 50 %). This correspond with then still larger role of public banks.
2. From about 1990 onwards, the role of the private banking system is increased. In the 1992 Maastricht Treaty, money creation became the exclusive prerogative of private banks. In 1999 the 1933 Glass-Steagall act on the was partially repealed by the Gramm-Leach-Bliley Act on the separation of commercial and investment banking was partially repealed.
3. Between 2000 and 2008 money creation accelerates, resulting in the 2008-financial crises.
4. In the early phases of the crisis, governments had to recapitalize the banks by issuing bonds. Government debt increased with a (modelled) average level of 20 %. It is striking that the total amount of M3-money nevertheless increases further. This could only be explained from additional money creation during the recapitalization. Apparently, a substantial part of the recapitalization was provided through additional money creation by (other) banks. This counter intuitive conclusion is supported by literature on the sovereign- bank nexus.
5. During the period 2010-2019, the now existing increased government debt was repaid by increased taxation. In combination with the continued money creation and thus M3-growth, this explains the period of zero-growth.
6. From 2012, and in particular from 20124 onwards the ECB runs its unconventional policy of Quantitative Easing in the Additional Purchase Program (APP), directed to repurchase the bonds which earlier were created for the bank resolution.
7. In 2019 the Covid-crisis provokes the need for additional liquidity. The money is created by the ECB in the Pandemic Emergency Purchase Program (PEPP). The pandemia is modelled through a 60 % reduction of labour and consumption during the year 2020. The overall effectivity at which the created 5000 billion euro reached the real economy, was estimated from the fit between model and statistics as 70 %. This is somewhat higher than other estimates (ref).
8. During 2024 and 2025, ECB has increased the policy rate to about 4 % in order to control inflation. This is modelled by an about 2% increase of the natural interest rate of about 2 % for a two years period.

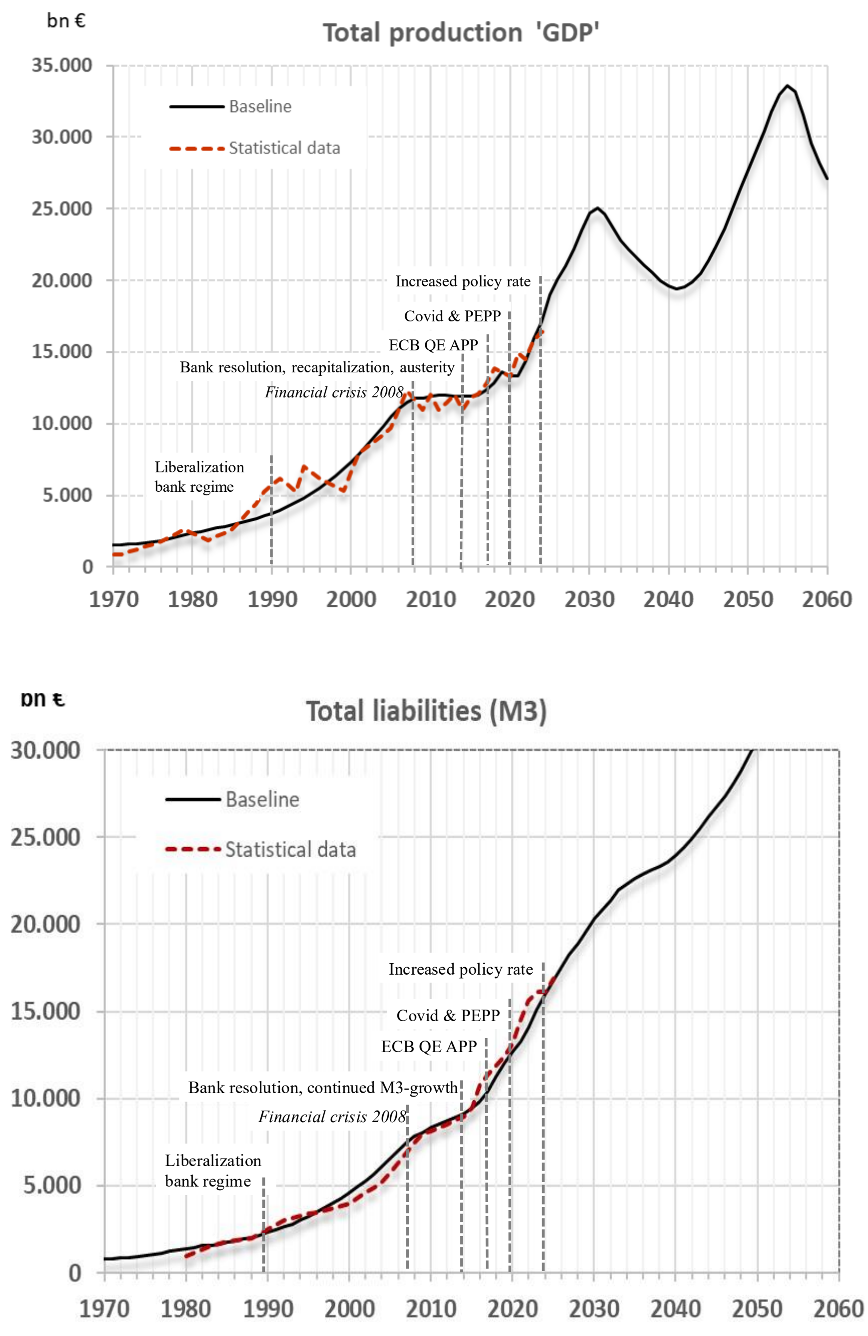



*Figure 9.2 Modelled and statistical developments of total production and total liabilities, explained from applied policies.*

It is concluded that the dynamical behaviour of the Eurozone financial-economic system can be satisfactory reconstructed by the model, when accounting for the respective policies which has been taken over time. This implies that the effects of future, alternative policies can be meaningful evaluated.