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Reforming the Eurozone financial system: A system-dynamics approach☆

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ABSTRACT

The effectiveness of the current monetary policy of the European Central Bank (ECB) in maintaining (price) stability in the eurozone is assessed using a system dynamic model. The model combines a neoclassical growth model with a stock-flow representation of the eurozone financial sector at a high level of aggregation. With endogenous money creation, the multidirectional relationship between asset prices and net income, and also the dual causality of both liquidity and investment relative to interest rates as the main features of the model, the developments of the past 50 years can be understood and extrapolated to 2050.

The simulation experiments indicate that the current pro-cyclic system is inherently unstable. This instability can only be overcome by monetary policy that eases and tightens the total amount of money in the system in a countercyclical manner. An obvious way to achieve this is the introduction of 100% Central Bank Digital Currency (CBDC). This calls for the ECB's mandate to become the sole "monetary authority" that creates and controls the amount of money in the system, with the sole and unambiguous objective of price stability. Money creation to achieve price stability at a targeted level of inflation with simultaneous repayment of public debt varies between €200 billion and €500 billion per year. This money can be channelled into the real economy through the EU's governance structure and spent on tax cuts and/or direct public investments, for example in physical and social infrastructure.

1. Introduction

The sustainability of the European Union (EU), and in particular the Eurozone, is highly dependent on its financial and economic system. Given the ongoing financialization of the economy (Lagoarde-Segot, 2017; Mazzucato, 2018) the role of the financial system is the most critical. After the huge recapitalization of banks after the 2008 financial crisis, increased taxation driven by austerity policies to restore government budgets, brought stagnation and large spread in bond-interest rates. To counteract these developments and in particular the persisting deflation, ECB started the 'whatever it takes' Quantitative Easing (QE) program, during which a net amount in the order of 5000 billion euro's was added to the liquidity of the overall system by buying back government bonds from financial markets. One of the aims was to increase inflation, but over the 10-year QE-period, inflation remained very low, leaving the 2% target out of reach. In the meantime ECB was criticized for violating its mandate by creating new money through the QE-program.

Inflation has been rising since January 2021. The 2022 energy crisis, caused by the war in Ukraine that started in March 2022, led to a sharp further rise in inflation, reaching a level of 10% and more in October 2022. Western central banks, including the ECB, responded by incrementally raising the 'policy rate' (since July 2022), with the intention of lowering inflation at the expense of lower economic activity. Against this background, the main questions in this document are:

- whether the instruments currently available to the ECB are up to the task of stabilizing the financial-economic system under the current and coming disruptive conditions;
- how the current system can be restructured into an inherently stable system, which is able to cope with the foreseeable future transitions (energy, climate change) and geo-political discontinuities;
- how the transition between the current and the future, reformed system can be made.

To this end, a system dynamic model was developed to study the

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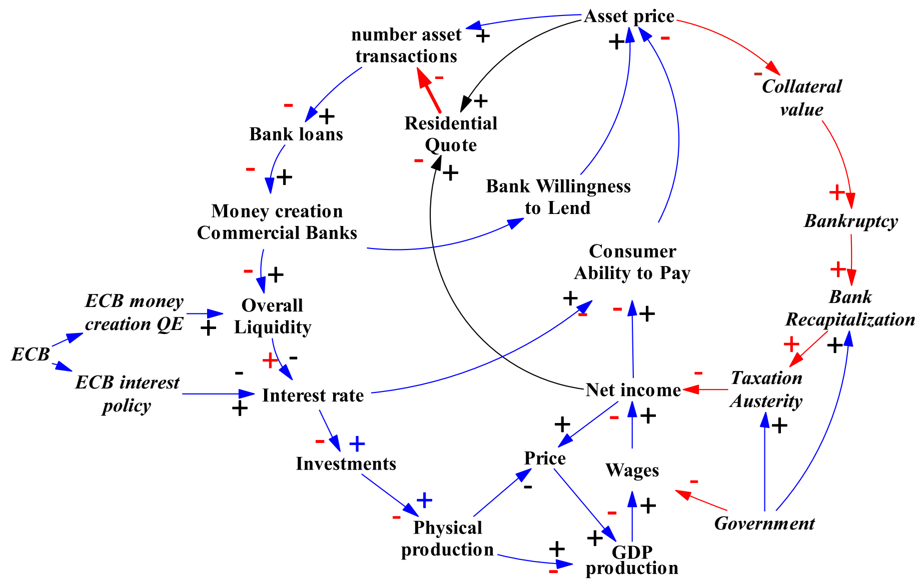

Fig. 1. Diagram of Causal Loops and associated processes of the modeled boom-bust cycle.

dynamic behavior of the current euro area financial system and explore more stable and sustainable alternatives.

2. Model structure

The system-dynamics model we developed aims to simulate the dynamic behavior of the financial-economic system over time, taking the most important interacting mechanisms into account. These mechanisms are described as cause-effect relationships, which can be numerically simulated on the basis of difference equations. The state of the system at a given time is numerically derived from the state one time step earlier and can be examined for cause-effect relationships and system stability.

The *economic system* is based on a neoclassical description of economic production. The system is modeled as a closed economy in which goods and services are produced using capital and labor as inputs for three economic sectors; a Manufacturing, a Service and a Government sector. Capital and labor inputs are based on marginal profitability considerations. Prices of manufacture and service goods and of labor (wages) are modeled by simulating by market mechanisms.

The *financial system* is modeled as an aggregate bank and has the structure of a bank balance sheet, with assets and liabilities. The deposit holders are private (production) firms, government, a (central) bank and four groups of consumers, having income from labor, real assets, government bonds and private firm shares.

The most pronounced dynamic behavior of both the real financial-economic system and the model is the boom-bust cycle. The current system has an essentially pro-cyclical character, given the many positive feed-backs in the system, which means that fluctuations in the system are self-reinforcing. As a result, growth in real and monetary output in the "boom" part of the cycle tends to continue until limits are reached, such as over-indebtedness and subsequent loan defaults. This upward "boom" part of the cycle will then be followed by a downward "bust" part, in which the self-reinforcing nature triggers physical and monetary contraction of the system. The main features of the underlying causal relationships (loops) are shown in Fig. 1. It shows how the inherent boom-and-bust tendency in the real financial system is simulated by the circular link between – asset prices – money creation – total liabilities/liquidity – interest rate – investment – physical production – wage levels – net income – price level (inflation) – GDP – consumer ability to pay – asset prices.

In the upward boom phase (blue +/−) symbols, left), rising asset prices, especially house prices, evoke a high level of asset transactions, high bank loans (mortgages), increasing money creation, increasing liquidity, lower interest rates, increasing investment, physical and monetary production, leading to higher wages, net income and thus a higher ability to spend more on housing. Together with the expectation of a continued future increase in income and house prices, this provokes the further increase in asset/house prices, after which the self-reinforcing cycle starts over again.

As soon as the level of over-indebtedness, as indicated by the ratio between costs of assets (housing) and net income, the so called 'residential quote', becomes too high (above a threshold level), market forces dictate that the number of asset transactions decreases (red arrow Fig. 1). This results in a lower level of total bank loans, thus lower money creation, higher interest rates, lower output, wages and income, and thus falling asset prices. The downward bust part of the cycle thus initiated, is also self-reinforcing, resulting in an ongoing decline in asset prices (red +/− symbols in Fig. 1). Herewith, the so-called 'Minsky moment' is reached (Minsky, 1982, p.34).

If the subsequent loss of collateral of the bank loans exceeds the bank's capital ratio, banks can go bankrupt and a full-blown financial crisis has become a fact. After the 2008-crisis the government was expected to come to the rescue by recapitalizing the banks through massive financial support (by increasing the sovereign debt). The concomitant increase in taxes and the reduction in government spending (austerity policies) exacerbate the economic decline (right-hand side of Fig. 1).

During the upward boom part of the cycle, the interaction of rising GDP, labor, wages, net income, consumption and asset prices causes rising price levels (of production and services goods) and thus higher inflation. In the downward crisis, inflation tends to get too low (deflation).

In the financial system of the euro area, the ECB's main task is to aim for a certain rate (2%) of inflation. To this end, the ECB manipulates the base rate. However, this tool is not very effective, works with a delay and, as will be discussed later, is potentially harmful to the economy as a whole. The other option is to create money. However, the ECB should not use money creation as a policy tool The combination of money creation in the hands of private banks and the central bank's rather ineffective interest rate policy is causing undesirable instability in the European economic and financial system.

A full account of the model, is given in the Appendix.

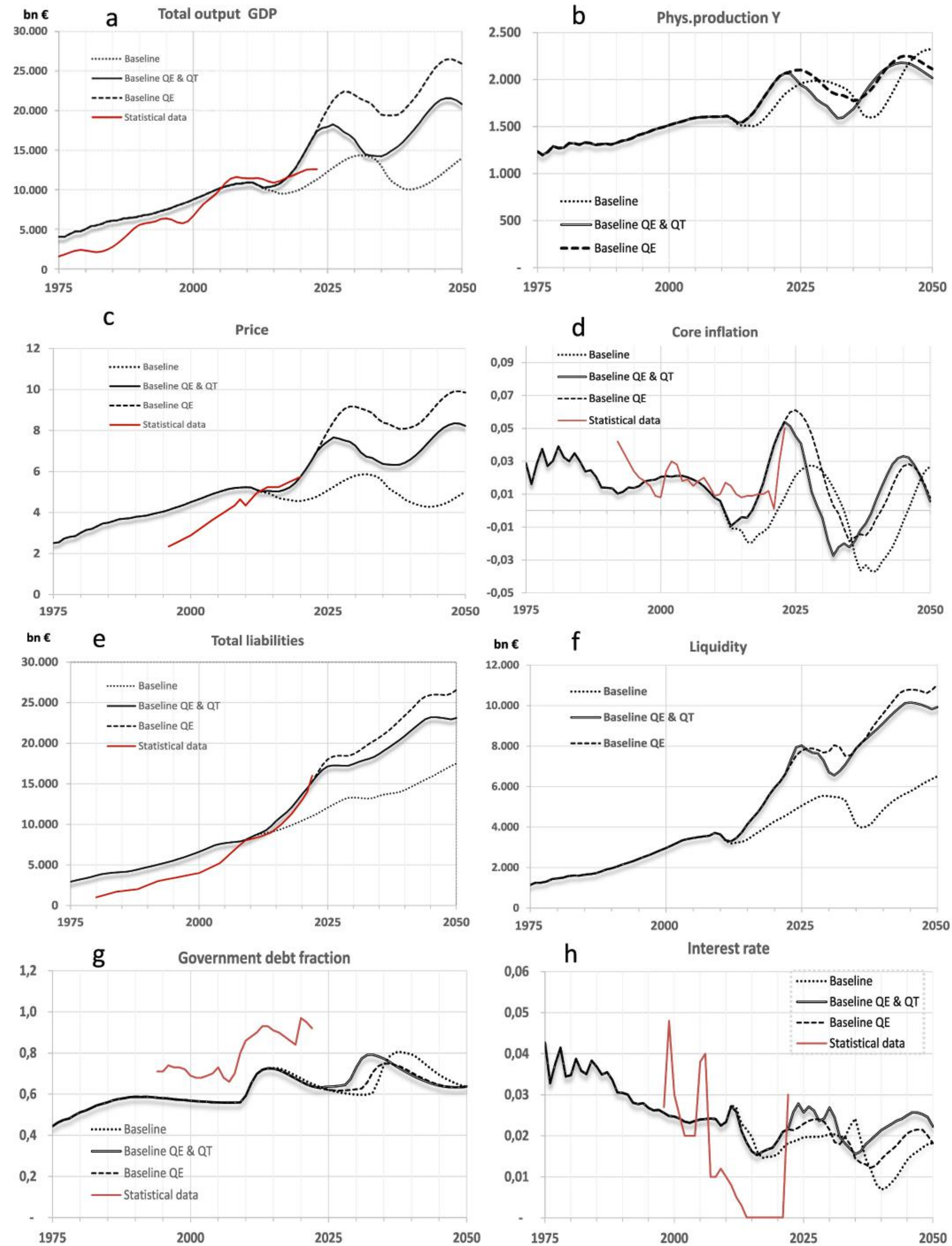
bn €
a
Total output GDP
Baseline
Baseline QE & QT
Baseline QE
Statistical data
b
Phys.production Y
Baseline
Baseline QE & QT
Baseline QE
c
Price
Baseline
Baseline QE & QT
Baseline QE
Statistical data
d
Core inflation
Baseline
Baseline QE & QT
Baseline QE
Statistical data
bn €
e
Total liabilities
Baseline
Baseline QE & QT
Baseline QE
Statistical data
bn €
f
Liquidity
Baseline
Baseline QE & QT
Baseline QE
g
Government debt fraction
Baseline
Baseline QE & QT
Baseline QE
Statistical data
h
Interest rate
Baseline
Baseline QE & QT
Baseline QE
Statistical data
1975
2000
2025
2050

Fig. 2. A. Current ECB non-standard policy measures:
system behavior in case of no policy measures (Baseline; dotted line), QE (broken line) and both QE and QT (solid, shadowed line); empirical, statistical data (red solid line).
B. Current ECB non-standard policy measures:
system behavior in case of no policy measures (Baseline; dotted line), QE (broken line) and both QE and QT (solid, shadowed line).

3. Model simulations

The model is applied over the period 1950 to 2050 (including model initialization) in order to study the effects of three categories of current and potential policy measures:

- ***Current ECB non-standard policy measures***; the development over time is reconstructed to study the effects of the actually realized QE- and current interest rate policies (denoted by ECB as 'non-standard' policies). As the current policies of increased interest rates intend to reduce the liquidity in the system, they will be denoted as Quantitative Tightening (QT). The actually realized historical development, which includes both QE and QT-interest policies, thus will be denoted as *Baseline QE & QT*. The effects of these policies will be further evaluated by comparing this historical Baseline QE & QT development with the hypothetical situation of no policy at all (*Baseline*) and of QE-interest policy only (*Baseline QE*).
- ***Alternative post 2022 ECB standard policies***; in this computational experiment it was assumed that, starting from 2022, the ECB's mandate or its interpretation will be extended to include (some sort of) money creation in addition to the money creation of private banks as a future 'standard' procedure (Central Bank Created Currency; CBCC). In this case, stabilization of the system, in particular the price level, is enhanced by the simultaneous, concerted deployment of CBCC-money creation and short term interest rate adjustments. In a second alternative, all money is supposed to have been created exclusively by the ECB as Central Bank Digital Currency (CBDC). The computational results for these alternatives will be denoted as *CBCC 2022* and *CBDC 2022*.
- ***Alternative post 2012 ECB standard policies***; in this 'what if'-scenario it is assumed that the CBCC- and CBDC-policies have been applied soon after the 2008-financial crisis. The computational experiment then enables an evaluation of these alternative *CBCC 2012* and *CBDC 2012* trajectories against the background of the actually realized historical development since 2008 (*Baseline QE & QT*).

3.1. Current ECB non-standard policy measures

In first instance, the model was run over the 100-years period 1950–2050 to calibrate the *Baseline QE & QT* version of the model, using historical data of core macro-economic indicators for the EU-economy in the period 1950–2020. On the basis of the calibrated model, forward simulations were made for the hypothetical *Baseline* situation without any policies and the effectuation of only QE-policy after the 2008-crisis (*Baseline QE*). The results are presented in Figs. 2A and B.

3.1.1. Reconstruction and comparison with statistical data

In first instance, the achieved correspondence is considered between the calibrated *Baseline QE & QT* development (solid shaded lines), and the statistical data on which the calibration was based (Trading Economics, 2023; solid red lines).

As shown in Fig. 2A it has been possible to reach a reasonable correspondence between the modeled and the statistical data for the most important parameters *GDP*, the amount of money in the system as given by *total liabilities*, the magnitude of the *price- and inflation* level and the level of the 'natural' *interest rate* during periods without interest rate policies.

For both *GDP* and *Total Liabilities* the discrepancy (as standard deviation) between the modeled and the statistical time series was calculated (as square root of the mean sum of squared differences).

For ***GDP*** the standard deviation between model and data over the period 1950–2022 is about 60%. For the more recent period 2000–2022 the standard deviation is only 10%. For ***total liabilities***, the standard deviation over the full period with available statistical data for the 1980–2022 period is about 35% which reduces to 6% for the more recent period 2010–2022. As shown in the Figures, the larger discrepancies result from the overestimation of the levels for GDP and total liabilities during the earlier period up to 2000. Likely this can be explained by the fact that the governing financial-economic mechanisms and related parameters are (deliberately) assumed to remain unaltered during the 100 year modeling period. However, given the liberalization (and digitalization) of the financial and economic system in the 1990s and the associated shifts in bank lending from the productive to the non-productive asset sector (Bezemer & Hudson, 2016), it is likely that the actual level of new money creation has been lower in the earlier period than assumed by the model for the entire modeling period. As a result the model overestimates the earlier levels of GDP and total liabilities. In the more recent period after 1990, the rate of money creation in the model corresponds more closely to real money creation, i.e. the increase in total liabilities.

The discrepancy in government debt as ratio of GDP is due to the model assumption that the EU-regulated maximum debt level is limited to 60% of GDP and is maintained at this level through higher taxes. In the real world as a result of bank resolutions following the 2008-crisis, the real (statistical) debt to GDP ratio in the Eurozone increased from 70% to 93% in 2014, slowly returning to a level of 84% in 2019. This explains the offset between the modeled and the real government debt fraction in Fig. 2A-g.

In sum it can be concluded that the overall functioning of the Eurozone financial and economic system can be broadly understood from the model and the core mechanisms it composes, of which the broad outlines were shown in Fig. 1.

3.1.2. Quantitative easing

According to its limited mandate (art 104 of the Maastricht Treaty), the ECB is not allowed to supply new money directly to the real economy via government spending and via other public authorities. As a 'non-standard' alternative, ECB has brought the money into the system along two alternative routes:

- via the purchase of government bonds and to a lesser extent also corporate bonds from non-bank financial institutions on private financial markets;
- via the purchase of bonds from private banks in the Eurozone; these bonds were obtained by the ECB in exchange for central bank reserves (liabilities) which these private banks then have at ECB (claims of private banks on the ECB).

Since 2019, the balance sheet was further elongated to mitigate the economic effects of the Covid-19 pandemic. In total, the QE-program had an overall extent of about 8000 bn €. This does not imply that this total amount of 8000 bn € has become available as liquidity in the real economy. As the purchases of bonds from private banks are 'paid' by ECB in ECB-reserves, liquidity will increase by a smaller amount. Over the full period from 2010 to 2022, about 5000 bn € was brought effectively into the financial system (ECB, 2023a).

The effects of the QE-program can be derived from comparing the model run with QE (*Baseline QE*; black broken line) with the run without

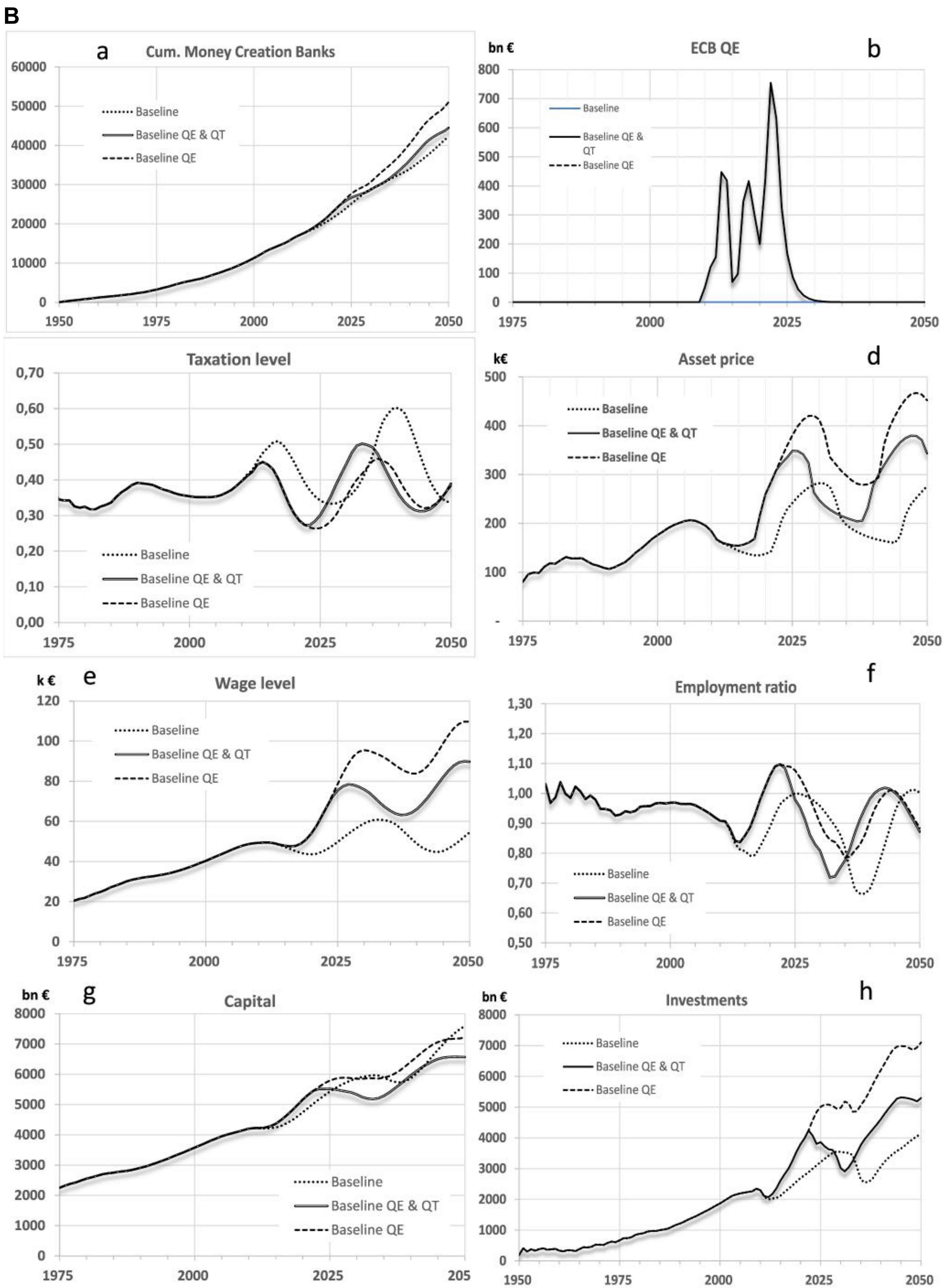

Fig. 2. (*continued*).

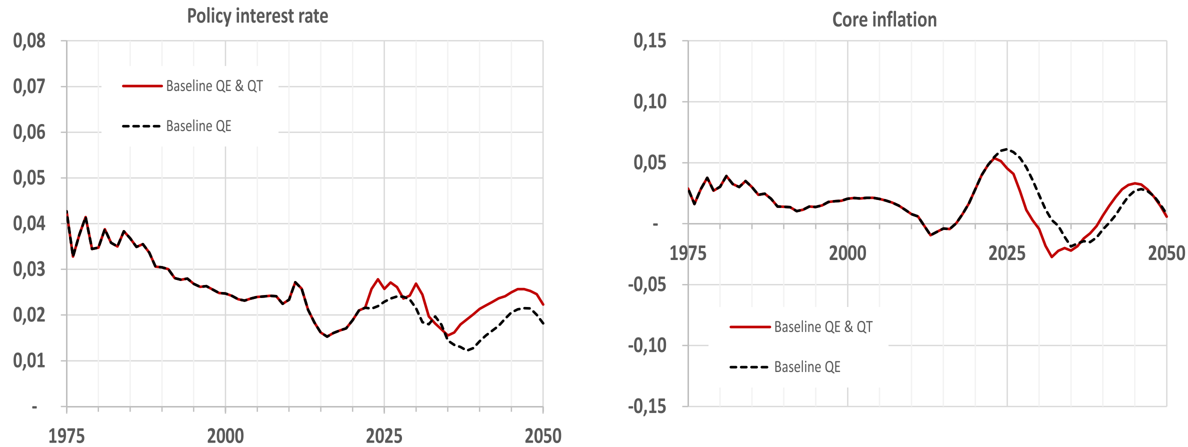

Fig. 3. Inflation due to 2 -years increased policy interest rate (starting 2022; red solid line) compared to the baseline development (black dotted line). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

any policy (*Baseline*; black dotted line; Figs. 2A and B):

- In the QE-program the post 2010 money creation by ECB to repurchase bonds (2B-b). primarily results in a higher price/ core inflation level (Fig. 2A-c,d). This subsequently leads to stronger increase in ***total liabilities*** (2A-e) and a stronger decrease in ***interest rate*** (2A-h), which gives rise to higher net ***investments*** (2B-h), thus also higher ***physical production*** (2A-b***)***. Herewith, ***employment*** (2B-f) increases, followed by increasing ***wage levels*** (2B-e***)*** and consumption.
- The modeled ***core inflation*** (2 A-d) starts to increase between 2015 and 2020 and is much higher in the QE-case than in the *Baseline* without QE. The simulated core inflation reaches values up to 6% around 2024, thus by far overshooting the 2%-target.
- The real, statistical core inflation (solid red line) starts to increase in Januari 2021, later than the modeled increase, but earlier than the start of the Ukraïne war in March 2023 and the subsequent energy crisis and energy price surge. Part of the strong increase in inflation is apparently the (delayed) result of the injections of large amounts of liquidity during the QE-program, as suggested by the model. Given the higher level of inflation under QE, also ***GDP (***pY; 2 A-a) rises markedly with respect to the baseline situation without QE.
- The ***Government debt fraction*** of GDP (2 A-g) remains unaltered under QE, as the level is dictated by the preceding 2008-crisis rather than by the QE-response to the crisis. Given the increase in economic activity, taxation in the QE-program is at a lower level, than in the hypothetical alternative without QE. Together with rising wages, and therefore net income, the ***price of assets*** also rises sharply.

Summing up in terms of the causal loop diagram in Fig. 1, the QE-driven increase in liquidity triggers a lower interest rate, which stimulates investment and physical production. As a consequence the need for labor increases, which calls for higher employment and thus higher wages. These higher wages allow higher asset prices (willingness to pay) and thus more money creation by commercial banks, which results in even more liquidity. The overall effect is a strong increase in price level (inflation) at a moderate increase in real, physical production until 2025.

These results are at least partly in line with several statistical studies to assess the effect of the QE-program (VAR -analysis):

- Lewis and Roth (2015) report that "the policy measures indeed appear to be successful in terms of real, physical production and employment, but also that these positive effects vanish after about 2025. While output rose immediately, the positive effect was short-lived and economically small; prices did not significantly respond to the shock (of the liquidity inputs)".
- Demertzis and Wolff (2016) state that "the monetary policy so far has helped to extend new credit to the euro-area economy and has positively contributed to growth. These effects are visible but small in relation to the size and type of monetary policy interventions".
- Gros (2016) concludes that "the bond purchases of the ECB have helped to reduce interest rates somewhat, especially for the countries facing high risk premia. But the program has not been effective in achieving the official goal of the ECB, namely bringing area-wide inflation closer to 2%". Gros holds that the importance of Quantitative Easing in the euro area has been vastly exaggerated. Gros' observation (in 2016) that the interest has been reduced 'somewhat' corresponds to the marginal decrease indicated by the model for the period 2010–2015. After 2015 the interest rate is increasing again.

3.1.2.1. Slow transmission through the system. Breuss (2017) reported that the QE-measures reach the real economy with a strong delay. This might be explained by the very indirect way in which the QE-money has entered the economy. When purchasing government bonds from private banks, the ECB 'pays' with bank reserves at ECB. Whether the money actually reaches the real economy depends on de extent to which private banks provide loans to firms and consumers. As indicated, during the earlier years after the 2008 crisis, this level of lending has been low. Secondly, a large part of the QE-money supply went into private financial markets. This money is to a large extent spent on financial and real asset speculations and enters the real consumptive economy only slowly, thus generating the intended higher inflation level later. However, the model only partly accounts for these delay effects. As soon as the substantial amount of new liquidity becomes available on the 'financial markets', from where the government bonds were bought, interest rate starts to fall and investment and thus production starts to increase. As this is soon followed by increase of inflation, the transmission in the model is faster than in reality, thus explaining the difference between model results and statistical real (core) inflation.

The ECB confirms the complexity at which monetary policies are transmitted through the financial –economic system. According to ECB (ECB, 2023b): "the process through which monetary policy decisions affect the economy in general and the price level in particular is characterized by long, variable and uncertain time lags. Thus it is difficult to predict the precise effect of monetary policy actions on the economy and price level".

A preliminary conclusion is that the QE program appears to be only partly effective, as a result of the slow transmission through the system. The transmission delays are stronger than suggested by the model.

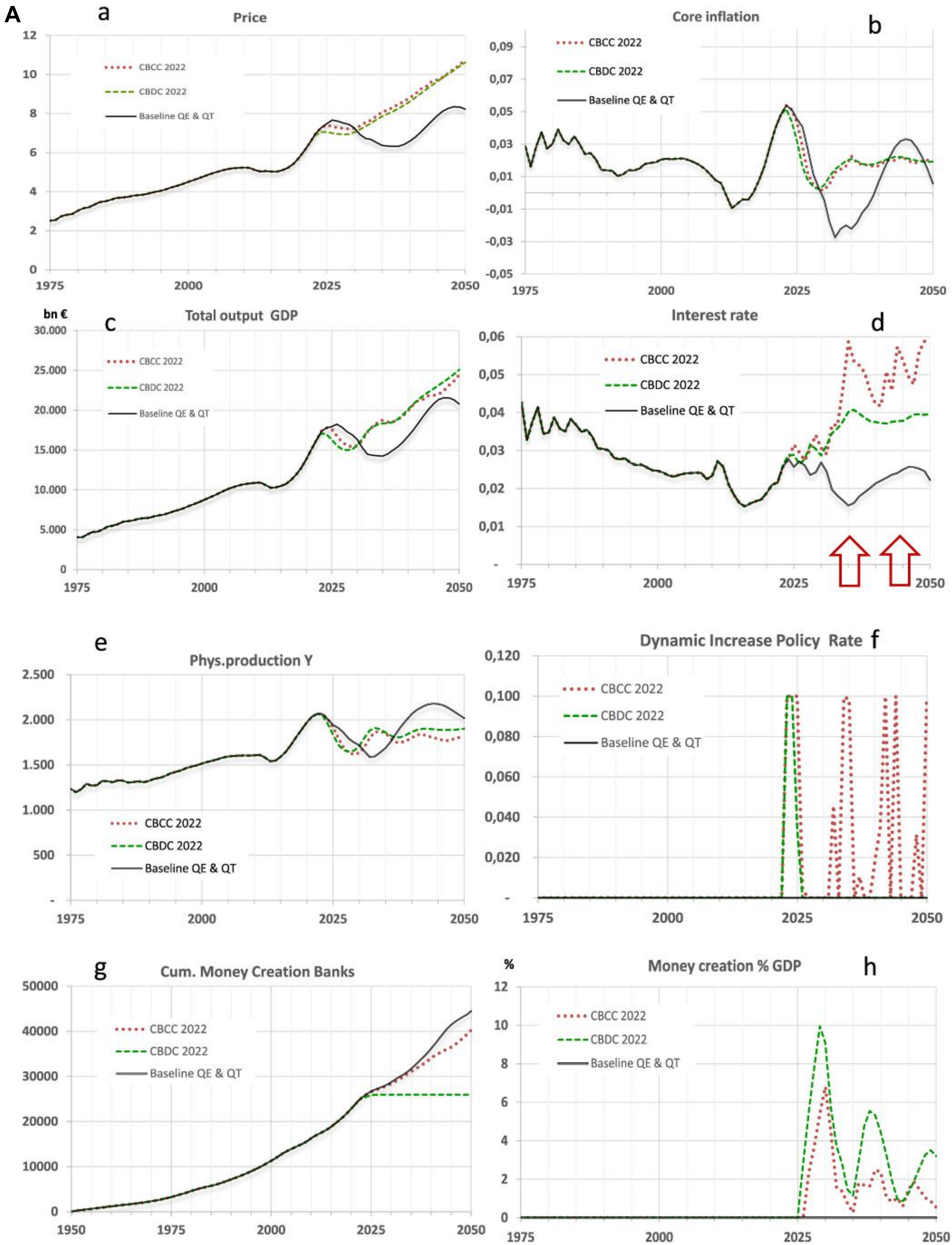

Fig. 4. A. Alternative post 2022 standard policies;
Simulation for the baseline incl QE and QT (black solid, shadowed line), application of CBCC (both ECB- and commercial bank money creation and dynamic interest policy rate;

red dotted line), and CBDC (100% money creation by ECB; green broken line).
B. Alternative post 2022 standard policies;
Simulation for the baseline incl QE and QT (black solid, shadowed line), application of CBCC (both ECB- and commercial bank money creation and dynamic interest policy rate; red dotted line), and CBDC (100% money creation by ECB; green broken line).

3.1.3. QT-interest rate adjustment policies

Overshooting the 2%-target, inflation thus has to be controlled otherwise, also in the case without the 2022 energy shortage and price surge. The current ECB-policy is to increase the interest rate on central bank reserves and thus on interbank lending in order to decrease economic activity, liquidity and inflation (Werner, 2011,p 25–33; Werner, 2012,p.1–17). To explore the effect of this 'quantitative tightening' (QT) by means of an increased interest rate, the simulated dynamical natural interest rate was forced to a slightly higher level during a two-year period starting in 2022.

As shown in Fig. 3, this small exogenously forced increase in the interest rate not only results in a significant and immediate decrease of inflation, but also decrease of economic activity. This negative effect is aggravated by several feedback mechanisms. The decrease in investment triggers a lower wage level and lower asset prices and thus less money creation. The forced rise in interest rates is therefore at the expense of investment and economic stagnation. In the model computation, the strongest deflation (negative inflation) is reached in 2030, after which the level of inflation starts to rise again and only reaches positive levels after 2035.

The resulting decline in the asset price level is such that it triggers a financial crisis after 2025 (which otherwise would have occurred a few years later). Raising the policy rate therefore carries the risk of exceeding the desired, limited reduction in economic activity.

Given the results discussed so far, the primary problem seems to be that the current control channels are too indirect to maintain the stability of the system. This in the first place holds for QT-adjustments of central bank interest rates, which slowly are transmitted to the broad money in the real economy. Also QE-liquidity supply is far too indirect. In the bonds-purchase program, the money primarily goes to institutional asset-investors in the financial markets, without reaching the real economy. The resulting delays, exacerbated by positive feedbacks, hamper the QE- and QT-interest rate policies. The risk of under- and overshooting the inflation target becomes significant, making it a process of trial-and-error.

3.2. Alternative post 2022 ECB standard policies; CBCC and CBDC

To improve the policies to control of the price stability two actions can be taken. Making the transmission channels for QE and QT as direct as possible can shorten the time lag for the policy measures to come into effect. Second, the respective mechanisms for easing (QE) and tightening the amount of money in the system (QT) can be coupled and controlled from a single set of criteria, from a single set of societal objectives, at the appropriate moment in time and thus preferably from a single monetary actor. This control comes down to:

- extending the amount of money (liquidity) through money creation by ECB as the 'monetary authority. In the process of money creation, the ECB (in cooperation with the national central banks) credits the well-defined amounts of new money to the EU-Treasury and/or the Treasuries of the Member States.
- reducing the amount of money in sequence of priority by less money creation, increased policy interest rate and/or eventually also tax measures.

These direct means of control then will enable a stable price / inflation level, which already for a long time is seen as the core activity of central banks. As the money then is created also, or even exclusively by the ECB as the single monetary authority, the amount of money in circulation can be adjusted continuously to the actual state of the economic system.

The restructuring of the financial system to take account of these fundamental requirements can be achieved in two ways by the introduction of:

- *Central Bank Created Currency* (CBCC), created and spent directly into circulation in the real economy by the ECB, but not exclusively. In this 'mixed model' both private banks and the public ECB create money. The current banking system remains unchanged. The CBCC might be a Central Bank Digital Currency (CBDC), which can be seen as the digital follow up of conventional cash money. CBDC is currently under discussion and can be legally introduced into the financial system at any quantitative scale, between, say 3% and 50%.
- *Central Bank Digital Currency* (100% CBDC), which is exclusively created by ECB. Commercial banks will no longer create 'money'. In this case of 100% CBDC, in which all money is exclusively created by the ECB, revision of art 104 of the Maastricht Treaty might be necessary.

Under both CBCC and CBDC the Central Bank creates money according to an explicitly formulated 'money growth rule', as proposed for instance by a Money Creation Committee (Jackson & Dyson, 2012). By giving such a money growth rule a legal, or even constitutional status, the fear that government agencies are seduced to create too much money becomes negligible.

The model assumes that the amount of money created, which is credited to central and or national governments, is more or less proportionally channeled to the real economy through tax reduction in combination with increased (physical, price corrected) government spending and through repayment of the government debt. However this expenditure is subordinate to the primary purpose of price stability.

Both CBCC- and CBDC- alternatives of money supply can be complemented with the reduction of money creation by commercial banks by means of more or less continuous adjustment of the interest rate. In that case, easing and tightening of the quantity of money are mutually balanced.

We use the model to study the effects of these CBCC- an CBDC-policies. Instead of the earlier discussed actually realized, incidental QT-increase of the interest rate in 2022, we assume that CBCC or CBDC is implemented in that year. The results are shown in Figs. 4 A and B.

3.2.1. Central Bank Created Currency (CBCC) 2022

In the CBCC-alternative, money is created both by private, commercial banks and by the ECB. The latter can create money to supplement the money supplied by the private banking system in order to achieve the 2%-inflation target. To this end, it might also be necessary to tighten the amount of liquidity in the system. The model computations assume that these concerted, short term easing- and tightening measures are effective from 2022 onwards. Both are controlled by the level of inflation: lower than targeted inflation requires additional CBCC-money creation (alongside money creation by commercial banks), higher inflation requires higher policy interest rates. In Figs. 4A and B the results for the *CBCC 2022* (easing and tightening) scenario are given by the red dotted lines and are compared to the *Baseline QE and QT* development (black solid, shadowed lines).

- In Fig. 4A-g the cumulative money creation by commercial banks is shown. After 2022 this money creation continues, be it at a lower level, as part of the money now is created by ECB, as presented in Fig. 4A-h.

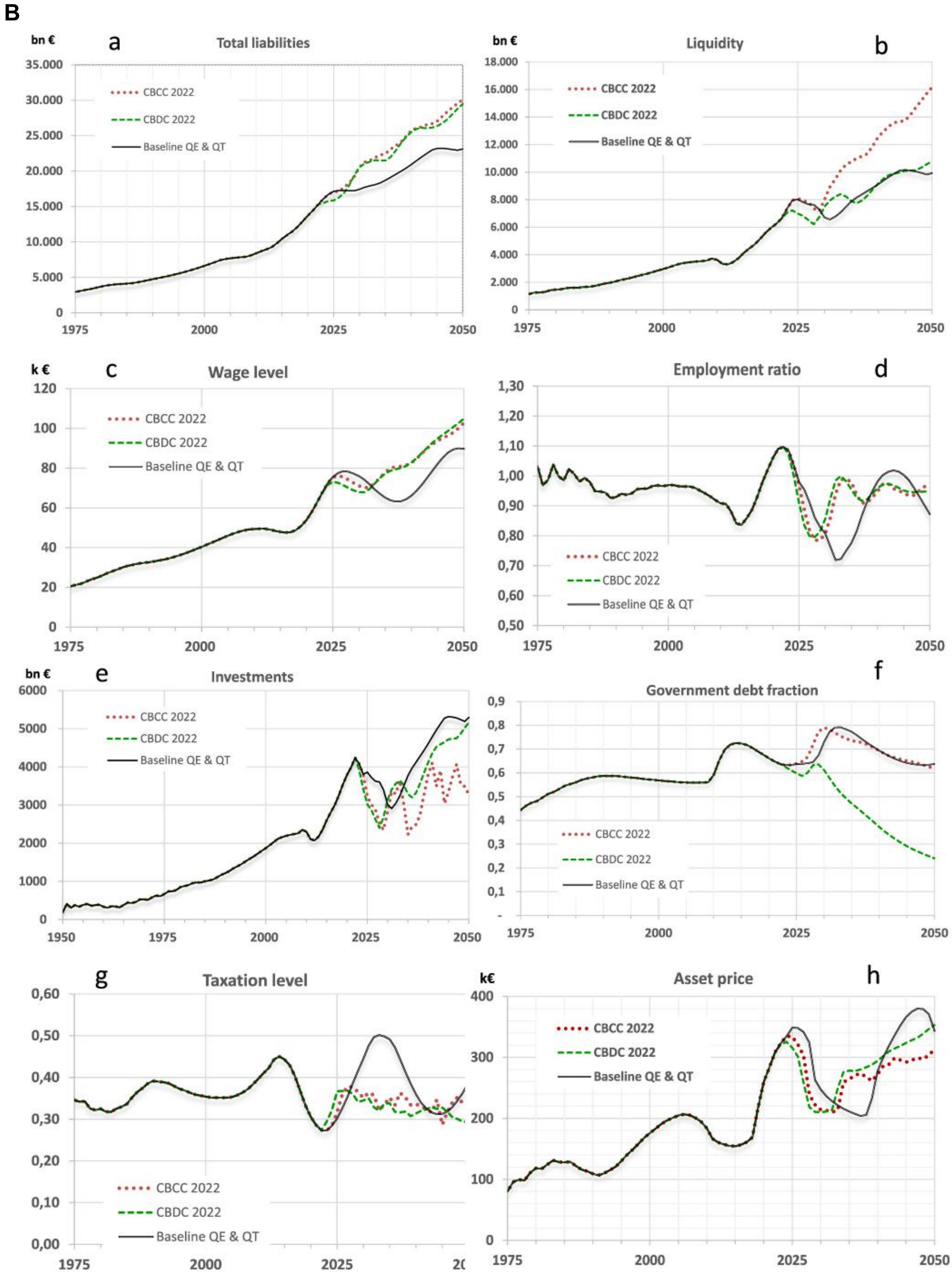

Fig. 4. (*continued*).

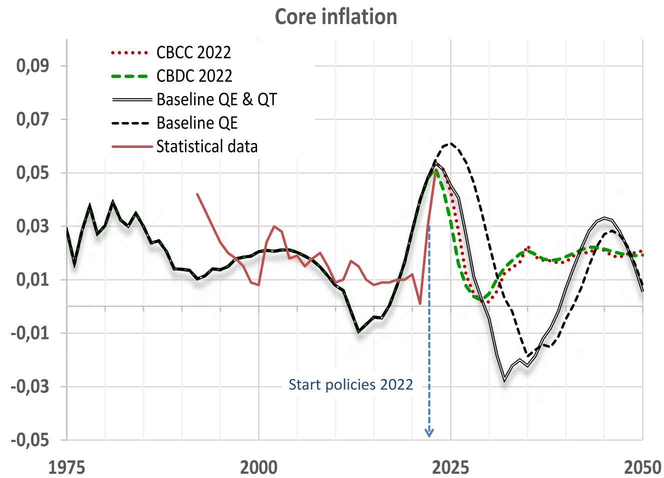

Fig. 5. Alternative post 2022 standard policies; effect of four 2022- scenario's on core inflation level.

- In Fig. 4A-f the required (dynamic) increase in the interest rate is shown. The resulting effects on interest rate are presented by the arrows in Fig. 4A-d. From both Figs. 4A-f and 4A-h, it can be seen how money creation and (dynamic) adjustment of the interest rate alternate.
- The rise in interest rate leads to an immediate reduction of investment (4B-e), followed by a fall in physical production (4 A-e), employment and wage levels (4B-c,d). Core inflation strongly drops to about 0.5% (4 A-b), which is less dramatic than in both the *Baseline QE and QT* - and the *Baseline QE* case. Nevertheless, as can be seen from the strong increase of government debt (4B-f), crisis occurs around 2030, just as in the earlier 2022 case of an incidental increase of the policy rate over a two-year-period.
- Nevertheless, after 2030 the financial system as a whole stabilizes, as can be seen from the results for employment, wages, asset prices and taxation (in Figs. 4B-c,d,g,h) and for physical production and GDP (4A-c,e).

The results for core inflation, now also including the *Baseline QE*-scenario and *statistical data*, are reproduced in Fig. 5:

After the sharp decline at the time of the policy implementation in 2022, the level of inflation increases again around 2027 and gradually converges to the 2%-level. Exceedance of this target level is prevented by the subsequent (second) increase of the policy interest rate (second arrow after 2030 in Fig. 4A-a). Under simultaneous control of both the (easing) money creation and the (tightening) interest rate increase, the fluctuations of the inflation level can be dampened and thus maintained reasonably close to the target level.

The CBCC-alternative thus offers great advantages over the current ECB-policies (QE and incidental QT- interest rate increase). This is the result of shifting about half of the required money creation from the private, commercial banks to the ECB, who brings the money into circulation when inflation falls below the target level, rather than the other way around. This implies that the control of the system becomes less pro-cyclic and more counter-cyclic, while the remaining pro-cyclic nature is counteracted by the successive increases of the interest rate.

These results suggest that (price) stability can be further strengthened by anticyclical creation of all money by the ECB. Such a system would come into effect through the introduction of Central Bank Digital Currency.

3.2.2. *Central Bank Digital Currency (CBDC) 2022*

As a further step in improving the (price) stability of the system, measures to ease and tighten the amount of liquidity could therefore be centralized at the ECB. As the single monetary authority, it then controls the total amount of money in the system, both by the exclusive creation of money and, also in this case, by (dynamic) adjustment of policy interest rate and eventually taxation. The money now is created by definition as Central Bank Digital Currency (CBDC). Private banks can no longer create money. They become intermediaries in loans that now come as 'loanable funds' from existing money on investment accounts. Both under CBCC and CBDC the Central Bank creates money according to an explicitly formulated 'money growth rule' such as the ECB 2% inflation target. Also in the CBDC-case, easing and tightening is as directly as possible controlled by the actual price /inflation level. In case the inflation falls short on the targeted inflation, additional CBDC-money is created and issued via government spending and/or reduction of taxation. In case inflation exceeds the target level, liquidity is tightened through proportional increase of the interest rate.

Just as in the previous case CBCC 2022-experiment, it is assumed that the introduction of CBDC is effectuated in 2022 in response to the high inflation level. In the same Figs. 4A and B, the results for *CBDC 2022* are given by the green broken lines:

- Whereas the increase in total liabilities (4B-a) is almost the same for CBCC and CBDC, Figs. 4A-g,h confirm that now all money is created by the ECB.
- The results for the temporal behavior of inflation are similar to the earlier CBCC-case. The immediate, but limited increase in the interest rate initially brings inflation down to 0.5% after which it converges to the 2% target rate.
- However, as an important difference, adjustments of the interest rate are hardly required in this case, as shown in Fig. 4A-f. Only a single adjustment of the interest rate occurs initially in 2022 to remove superfluous liquidity from the system. For the remainder of the period, the inflation level can be maintained around the target level, through money creation only. This is the result of the much larger, total volume of money, which is now being created countercyclically by the ECB. At the targeted 2% inflation rate, the volume of the controlled annual inflow of money is then large enough to control the overall amount of liquidity. As a consequence, the stability of the system is far less dependent on 'trial and error' interest rate policies, of which the negative effects for the economy as a whole are hard to predict.
- Related to the nearly absence of interest rate (increasing) interventions, the interest rate under CBDC stabilizes on a level of 4%, whereas the many interventions under CBCC accumulate to a level of 6% towards the end of the modeling period (4 A-d).
- The level of liquidity (4B-b) under CBDC is (much) lower than under CBCC. This is because commercial banks refrain from creating money and thus from financing (real) assets by means of new money. Instead, asset transactions have to be financed by existing money, which thus loses (part of) its liquidity, i.e. its availability for other investments. As a consequence liquidity under CBDC is less than under CBCC.
- The stabilization of the system is even more effective under CBDC than under CBCC. As shown in the respective Figs. 4A an B, the differences between CBDC and CBCC are small for price level / inflation, wage and employment levels, overall (GDP) level and, to some extent, physical production. With respect to investments and asset prices, CBDC policies achieve a higher level of system stability (4B-e,h).
- Under CBDC and CBCC, taxation levels are almost the same, and significantly lower than in the Baseline cases. However, the most striking difference is about the government debt, which is gradually paid off under CBDC, as shown in Fig. 4B-f. Herein, the rate of repayment is subordinate to maintaining price stability / inflation target.

It is concluded that effective stabilization of the inflation level, and herewith the financial-economic system as a whole, requires concerted

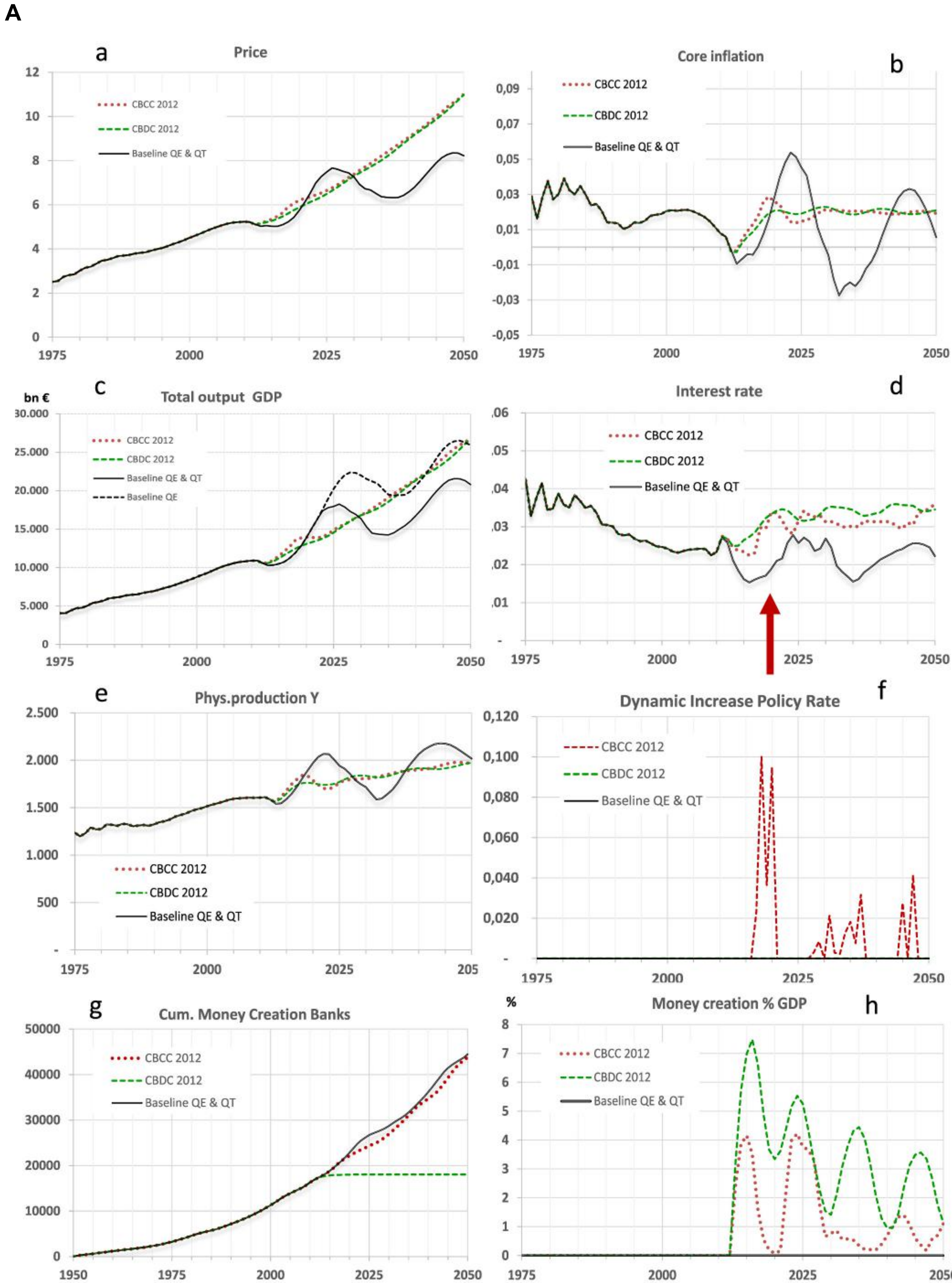
A
a
Price
CBCC 2012
CBDC 2012
Baseline QE & QT
b
Core inflation
CBCC 2012
CBDC 2012
Baseline QE & QT
c
bn €
Total output GDP
CBCC 2012
CBDC 2012
Baseline QE & QT
Baseline QE
d
Interest rate
CBCC 2012
CBDC 2012
Baseline QE & QT
e
Phys.production Y
CBCC 2012
CBDC 2012
Baseline QE & QT
f
Dynamic Increase Policy Rate
CBCC 2012
CBDC 2012
Baseline QE & QT
g
Cum. Money Creation Banks
CBCC 2012
CBDC 2012
Baseline QE & QT
h
%
Money creation % GDP
CBCC 2012
CBDC 2012
Baseline QE & QT

Fig. 6. A. Alternative post 2012 standard policies;
Simulation of the Eurozone economy under the assumptions of CBCC, with (black solid) and without repay of government debt (red dotted line), and CBDC, with 2% inflation, starting in 2012 (green dotted line).
B. Alternative post 2012 standard policies;
Simulation of the Eurozone economy under the assumptions of CBCC, with (black solid) and without repay of government debt (red dotted line), and CBDC, with 2% inflation, starting in 2012 (green dotted line).

and simultaneous control of 'push and pull' respectively easing and tightening directed policy measures. This most optimally can be achieved in a CBDC-system in which the ECB exclusively controls the total amount of money in the system by money creation, nearly without adjustment of the interest rate. In such an countercyclical system, price stability can be optimally maintained, while the risk on stagnation of the economy as a whole is minimal. A CBCC-system, in which the current role of money creating private banks remains unchanged, but the ECB can also create money, complementary to the current (Central Bank) interest rate policies, would already be a significant improvement of the stability of the current system.

3.3. *Alternative post 2012 ECB standard policies; CBCC and CBDC*

The results of the post 2022-experiments raise the question of what the temporal behavior of the financial-economic system would have been, if a CBCC- or CBDC-policy had been introduced shortly after the 2008-crisis. So in a final experiment, it is assumed that in 2012, shortly after the 2008-financial crisis, the mandate of the ECB (or its interpretation) would have been broadened, allowing the creation of money. Apart from comparison with the actually realized QE- and QT-measures, this would also allow comparison of the CBDC- and CBCC- alternatives over the longer period 2012–2050. As in the previous experiment, in both alternatives the stability of the system is controlled by concerted alternating of money creation and (dynamic) adjustments of the interest rate.

In Figs. 6A and B, the results are presented for *CBCC 2012* (red dotted line) and for the (100%) *CBDC 2012* system (green broken line):

- In the CBDC-case, all money is created by the ECB, initially amounting to about 5% of GDP, decreasing to 2 to 3% later (Fig. 6A-h). In Fig. 6A-g, it is shown that in this case money creation by private banks no longer takes place after 2012. Fractional reserve banking has made way for full reserve banking. The price level is now steadily maintained around the 2% inflation rate (6A-b). As the amount of money in the system is now fully under control, there is no 'excess' liquidity and the interest rate resumes its role as the market price of money in between supply and demand, stabilizing between 3 and 4% in Fig. 6A-d. The physical production (6A-e) follows a path of stable, continuous growth, while maintaining long term full employment (6B-f). Asset prices (6B-a) now follow the stable growth of the overall price level (6 A-a) and income / wage level (6B-c). More general, the stability of all macro-economic parameters is significantly increased. The simulation over the longer term thus supports the earlier conclusion that stability indeed can be achieved through concerted countercyclical easing and tightening of the amount of money in the system.
- The macro-economic differences between the CBCC and CBCC-scenarios are small. Outspoken difference is the government debt, which is almost fully repaid in the CBDC-scenario (6B-b), and the lower taxation level (6B-h). This is explained from the seigniorage on money creation that now benefits the public sector.

- Under the CBCC system, (price) stability requires additional, continuous (dynamic) adjustments, i.e. increases of the interest rate (Fig. 6A-d and f). But even then, the now relatively modest decline in the still boom-bust driven asset price development is causing a financial crisis around 2025.
- In contrast under CBDC, financial crises remains absent over the full period 2012–2050. Not a single interest rate adjustment is needed over the full period between 2012 and 2050 (6A-f)). Just as in the CBDC 2022 -experiment, this can be understood from the stocks (levels) and flows in the system.

The amount of money that the ECB has to create from the perspective of price stability, is in the CBDC-system about two times as large as in CBCC. The larger flow under CBDC allows for better control of the level, i.e. the amount of money in the system. Moreover this control is based on the countercyclical money creation at the right moment (at lower inflation levels). Under these circumstances the targeted (inflation) level can be maintained by controlling only the inflow of created money and the natural outflow of repaid money. In that case there is no need to pursue a likely adverse interest rate policy. This control of the system is further enhanced by spending the money into circulation directly through the real economy, rather than indirectly through the financial markets.

4. Conclusions

Our model simulations indicate that the ECB Quantitative Easing (QE) program has been only partially effective in restoring the targeted inflation rate after the austerity policy following the 2008 financial crisis. The transmission of the newly created money through the system was too slow and too indirect. Inflation thus initially remained too low for a long period, after which it became so high, that it had to be controlled otherwise by interest rate policies. However these policies might have severe negative effects on the economy as a whole, including the risk of provoking additional crises.

The model also illustrates that the stability of the system can be significantly enhanced by the partial or full transition from the current pro-cyclical to a countercyclical system. This can be achieved through simultaneous and concerted deployment of policy measures which both widen and tighten the total amount of money in the system, respectively by means of money creation and (dynamic) interest rate adjustments.

As a partial transition, the ECB can then create money as a Central Bank Created Currency (CBCC) alongside commercial banks, which still create pro-cyclical money when making loans. However, according to the model, the ECB's countercyclical money creation still needs to be supplemented by continuous, (dynamic) adjustments of interest rates. While future crises are still likely to occur, this modest reform can already significantly increase price and overall stability and provide a viable and effective transition path to the superior CBDC system.

In the modeling experiments, instability could be completely eliminated by complete countercyclical money creation in the form of Central Bank Digital Currency (CBDC). The model suggests that in a 100% CBDC financial system, which would have been implemented after the previous crisis of 2008, price stability would be maintained and future crises would not occur. Over the entire modeling period between 2012 and 2050, no interest rate adjustment was required. The increased volume of countercyclical money creation under 100% CBDC allows for adequate dynamic control of liquidity and inflation, making interest rate policies with potentially harmful effects on the economy as a whole unnecessary.

This calls for the ECB to be a single 'money-authority' that controls the amount of money in the system, from a single objective. If this objective is price stability in the (public) economy at large, rather than the profitability of private actors within that economy, an overarching public institution (like the European Central Bank) is the most

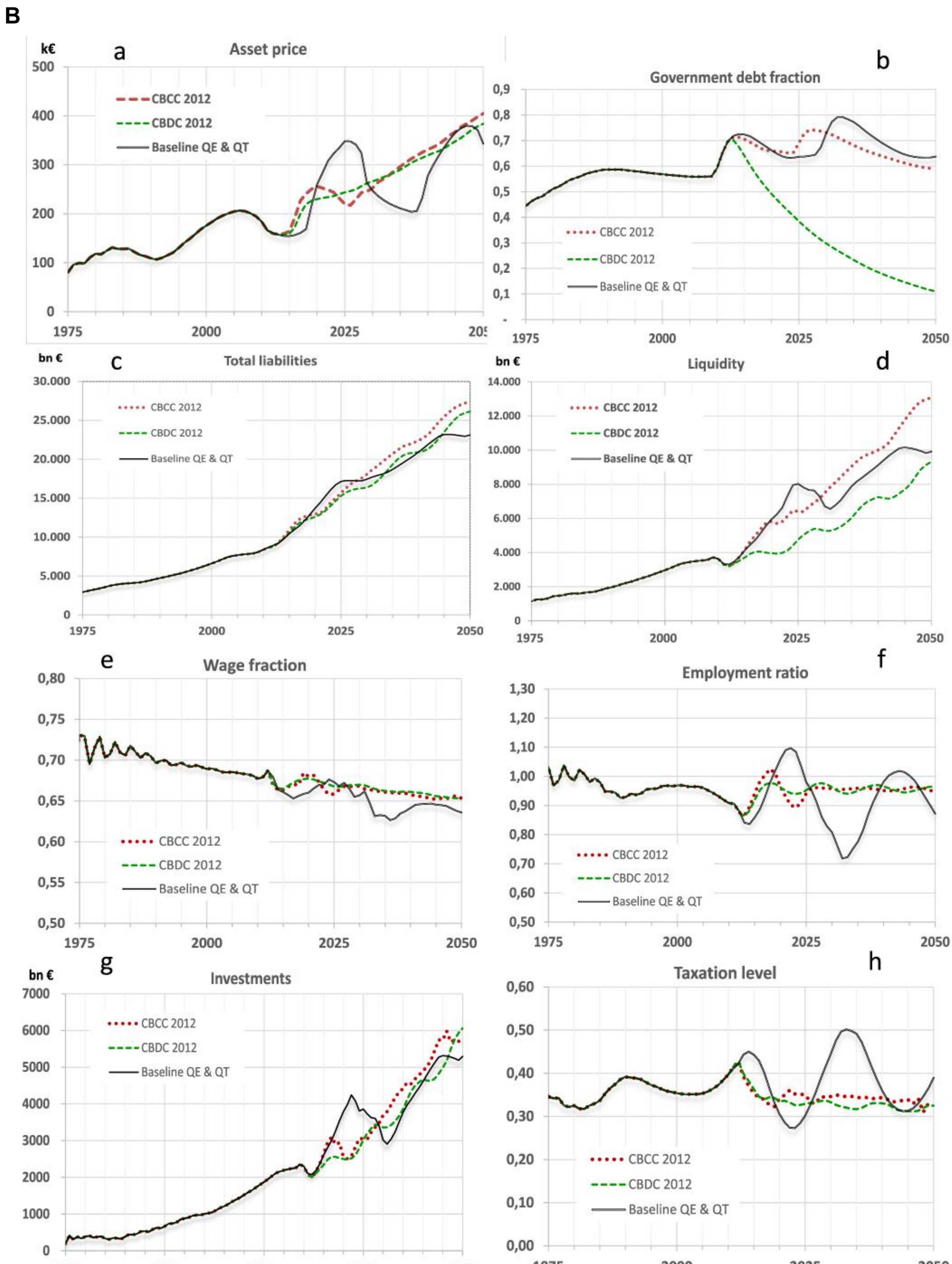

Fig. 6. (*continued*).

appropriate entity. To this end the ECB's mandate will have to be extended by amending Art 104 of the Maastricht Treaty, which will allow the ECB to create money within well-defined, constitutionally defined regulations.[1]

In addition to a higher degree of resilience to future discontinuities, the CBDC system brings additional benefits with regard to the unbundling of private and public roles and responsibilities. Bank runs no longer occur and banks are no longer too big to fail. A very important additional benefit is that the complexity of the system can be greatly reduced, allowing for much more effective supervision of the financial system as a whole. Complexity will be accommodated by the financial markets, on which commercial banks operate as service financial intermediaries/brokers (Werner, 2016;p. 361–379). Given their unique risk management expertise, the business model of these private banks can be considered robust.

In both the CBCC and CBDC alternative policies, the responsible EU public institutions can channel the (public) share of money creation (200 and 500 billion € / year respectively) in the real economy by repaying public debt, by investing directly in democratically chosen projects in the areas of physical (roads, railways, renewable energy, Green Deal etc.) and social (health, railways, renewable energy, Green Deal, etc.) education, etc.) infrastructure and/or low-interest loans to commercial, intermediary banks that can lend the money to private investors, including small and medium-sized enterprises.

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Data availability

Not of application

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Appendix: Eurozone Sustainable Finance Model: model description

The Eurozone Sustainable Finance Model (ESFM) simulates the dynamic interactions in and between the economic and financial system in the Eurozone. The model explicitly simulates the dynamic, non-equilibrium nature of the economy and the money stocks and flows in it, following the stock-flow consistent modeling approach (Carnevali, Deleidi, & Passarella, 2019; Godley & Lavoie, 2007). It also builds on Hallegatte et al. (2008, p.55-77), Yamaguchi (2010, 2015), Jackson and Dyson (2012), Benes and Kumhof (2012), van Dixhoorn (2013), Meijers and Muysken (2016), van Egmond & de Vries (2020) and Li and Wang (2020).

A.1. Model structure

The structure of the ESFM is given in Fig. A1.

The *economic system* is modeled as a closed economy in which goods and services are produced using capital and labor 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 modeled via (CES-CD) production functions, which account for the gradual shift from labor to capital as contributing production factors (left hand side Fig. A1). Capital and labor inputs are based on marginal profitability considerations. Prices of manufactured goods and service, labor (wages) and assets are simulated by supply-demand equilibrating mechanisms with delay. The (natural) interest rate is modeled as a function of supply and demand of money.

The *financial system* is modeled 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 Labor but also from increasing Asset prices and having government Bonds;
- LAD- consumers who, apart from Labor, have additional income / wealth from increasing Asset prices 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 LAD-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

[1] The prohibition to create money in support of the government and other public authorities is laid down initially in the Maastricht Treaty (as article 104) and in the 1999 protocol concerning the Consolidated versions of the Treaty of the European Union (Office Journal C 202, 59. June, 7 2016.). Herein article 123 states that overdraft facilities or any other type of credit facility with the ECB or with the national central banks in favor of public bodies shall be prohibited, In contrast, according to art 128, the ECB shall have the exclusive right to authorize the issue of euro banknotes which have the status of legal tender within the Union. It is a juridical question whether ECB is already mandated through art 128 to issue CBDC, alongside the current money creation of commercial banks (the CBCC case). In case of 100% CBDC, with money creation exclusively by ECB, most likely art 128 has to be adapted.

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. The *government* redistributes wealth by taxation and social payments and invests in societal functions.

The model covers the period 1950–2050. Economic activity is driven by three exogenous time-series: population (growth) and with it the available labor force, the (growth of) labor and capital productivity and the (change in) ratio between consumption of manufacturing and service sector output. All other dynamics stems 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).

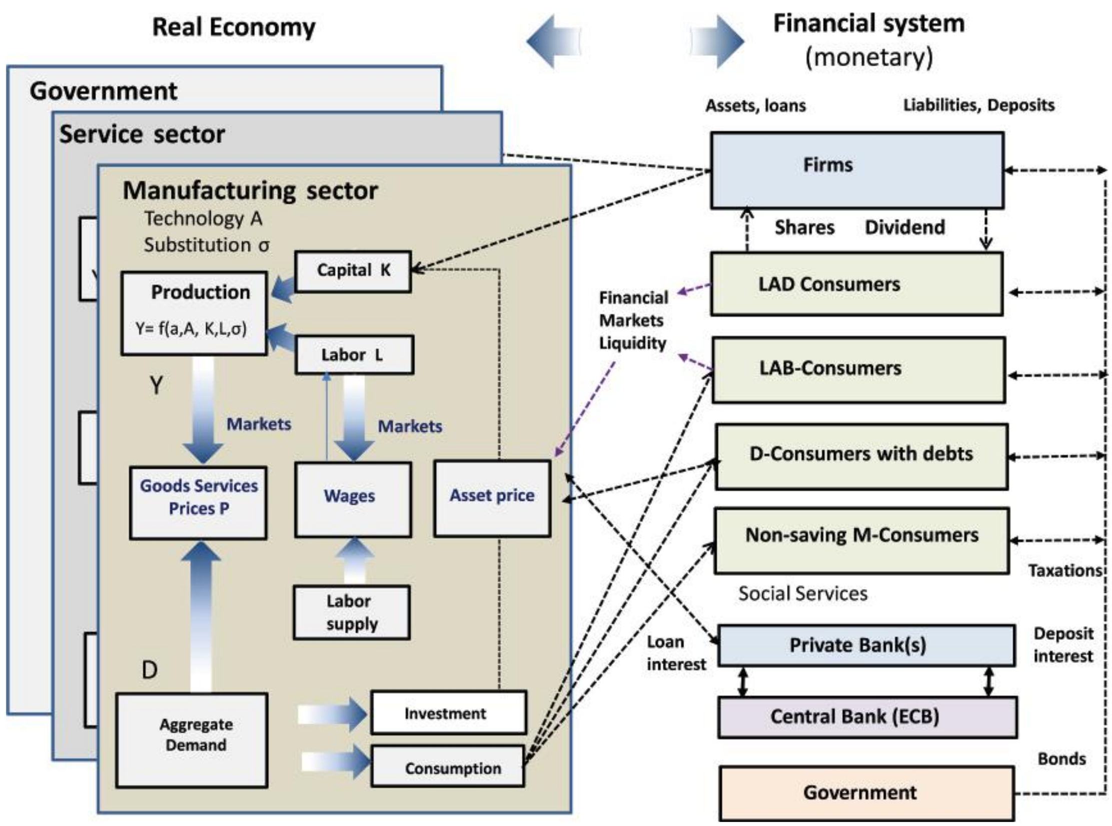

Fig. A1. Overall scheme of the ESF-model.

A.2. Dynamic processes

A.2.1. Production

Goods and services are produced using investments (€/yr) and labor (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 & Victor, 2016,p.206–219)[2,3]

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

with ‘a’ the parameter which distributes production (initially) to capital K and labor L and A representing technology- and organization-driven increase in labor productivity. The factor A is assumed to increase linearly over time. We chose a CES production function to represent an ongoing substitution of labor by capital. This is achieved by increasing the values for σ (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). The complementary decrease of the wage fraction was shown in Fig. 6B-e.

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

$$pY = I + C = wL + \pi_{gross}\ [€/\mathrm{yr}] \tag{2}$$

[2] 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.

[3] Physical stocks and flows are indicated with the letter G; monetary stocks and flows in Euros (€).; and labor inputs in fte's.

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

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

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

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 π_K of investing additional capital. The additional costs of an increase dK is p_K (ρ dK + δ dK + ε *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 can now be expressed as:

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

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

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

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 τ_K.

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

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

The additional labor input results in decreasing marginal labor productivity $\partial Y/\partial L$ 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:

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

As long as an additional unit of labor yields an (expected) net gain, that is, p dY > w dL or pY > wL/(1-α), more labor will be hired at a rate proportional to the marginal labor productivity expressed in wage units p (∂Y/∂L) /w.[4] The response parameter τ_L represents labor market frictions and inertia. The potential labor force is assumed to be 50% of the EU20-population.

The above equations describe the dynamic processes of investment and labor force and the balance equation for the different economic sectors. Note that this description does not assume equilibrating of prices and volumes on markets at the end of a period. Instead, the tensions between supply and demand generate changes in the next period. 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).

A.2.2. Price, inflation

Via a price-adjustment market mechanism, supply and demand are driven towards equilibrium. (Hallegatte et al., 2008). If actual output ('supply') Y differs from the aggregate demand D, being the sum of consumption and investment, there is a surplus (inventory) or a shortage (unmet demand) 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:

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

with τ_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.

A.2.3. Wage levels

A similar adjustment mechanism is supposed to operate on the labor market. In a market economy, a shortage of labor 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):

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

The wage rate 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. If actual employment e exceeds this desired level of employment e_{des} in a tense labor market, w tends to

[4] 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 labor force expansion has fallen to zero. This is the equilibrium value to which the simulated economy tends to go.

rise. When employment falls below the desired level, wages will start to fall. τ_w is again a response parameter.

A.2.4. Interest rate; dual causation

In modeling 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.

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. 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 $M_{liq\ ass}$ and the relative change in the liquid money stock $M_{liq\ ass}$:

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

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.

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, d_{demand} and d_{supply} are the respective weighing coefficients to empirically balance these different responses.

In contrast to the first two terms of eq.10, which represent the '*natural' interest rate* as based on the actual state of macro-economic parameters, the third term P_{ir} 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 eq.10, this policy option can be simulated, while keeping the dynamical behavior of the system (as given by the first two terms of eq. 10) intact. Example of the resulting system behavior is given in Fig. 3 of the main document.

A.2.5. Asset prices and asset price crisis

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 & 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 & van Dijk, 2023). The study showed that the '*ability to pay'* is the most determining predictive factor for housing prices. 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' R_{asset}, 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 '*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 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.

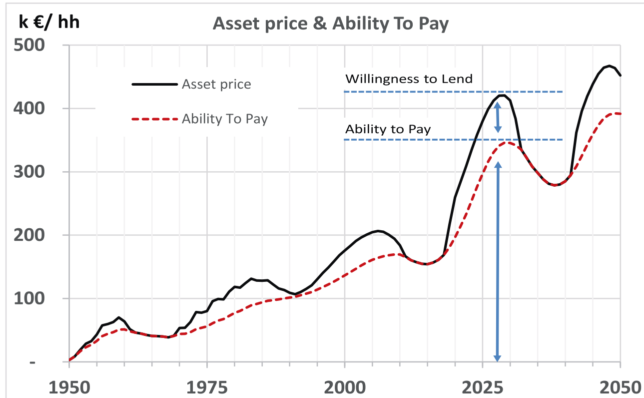

Fig. A2. Asset price as the sum of the Ability to Pay (AtP) and Willingness to Lend (WtL).

Let us assume that households on average have the ability to spend a fraction R_{atp} of their net income on financing their house and that the period t_{inc_exp} is the number of years over which households expect the current income growth to last. We also assume that the mortgage has to be repaid in t_{repay} years. To formalize this mechanism, the asset price p_{asset} is calculated as:

$$p_{asset} = (AtP + WtL)/\left(1/\tau_{repay} + \rho + BM\right) \text{ (€/household)} \tag{11}$$

with AtP = R_{atp} · (net income) and WtL= $d\,AtP/dt$ · t_{inc_exp}; $p_{asset} = p_{AtP} + p_{WtL}$

Herein, ρ is the *interest rate* and the *bank mark up* BM is the additional fee required by the bank (1% in current computations).

The yearly number of transactions for existing housing and new housing n_{trans} is assumed to be a fixed fraction (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 of the asset price needs to be financed additionally. 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:

$$BLF_D = n_{trans.}\, p_{ass}.F_b \tag{12}$$

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 LAD-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' thus can be defined as:

$$F_{loanf} = A_m . \frac{dM_{liq}}{dt} \tag{13}$$

The amount of loans given by banks BL_D, and herewith the amount of newly created money MC_{banks}, then is given by:

$$MC_{banks} = BL_D = \left(1 - F_{loanf}\right).BLF_D \text{ (€/year)} \tag{14}$$

Asset price crisis is initiated once the overall residential quote R_{asset}, covering the actual (AtP + WtL-asset price) reaches the level of 50%. The only subsequent assumption then is that the asset / housing market will respond to the high asset price level with a reduction of transactions n_{trans} (from 5 to 2.5% per year). According to eqs. 12–14, 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 eq. 11 this decrease in AtP will result in a strong decrease of p_{WtL}, the WtL-component of the asset price. As shown in Fig. A2, this then results in a significant decrease of the total asset price, which reinforces a further decrease through the same vicious circle.

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.

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.

A.2.6. Endogenous 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 (LAB- and LAD-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', 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.[5] 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.

Money creation by commercial banks is given by the sum of the respective bank loans to D-consumers, firms and government:

$$MC_{banks} = BL_D + BL_{firms} + BL_{gov} \text{ (€/year)} \quad (15)$$

The new money is created within the constraints mentioned above. In practice, this limitation can be circumvented (Werner, 2016).

A.2.7. Monetary policies

In the model, money is created by commercial banks eq. 15), by ECB or by both. 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 by ECB is directed to maintain the inflation rate dp/p around the inflation target $[dp/p]_{target}$ (2%):

$$\text{If } dp/p_{\text{}} < dp/p_{target} : MC_{CB} = -\left(dp/p - dp/p_{target}\right).F_{MC\ CB} \text{ (€/year)} \quad (16)$$

In the alternative policies, money creation is combined with dynamic interest policies (increase). Both measures are complementary with respect to the deviation from the inflation target level. The dynamic interest rate increase as applied in eq.10 thus is modeled as;

$$\text{If } dp/p > dp/p_{target:}\ d\,P_{ir} = \left(dp/p - dp/p_{target}\right).F_{Pir} \text{ (€/year)} \quad (17)$$

In eq. 16 and 17, $F_{MC\ CB}$ and F_{Pir} are multipliers to adjust money creation and interest rate increase to achieve optimal price stability.

A.2.8. Minsky moment; financial crises

As indicated above, in particular in A2.5, 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 – decreasing asset prices – decreasing money creation – less increase of total liabilities / liquidity – increasing interest rate – less investments – less physical production – lower wage/ price levels – lower net income – decreasing asset prices.

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 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).

A.3. Stock-Flow model structure

The *financial system* is modeled 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 four groups of consumers. The flows of money in the financial system is governed by the dynamical model behavior which was described so far in chapter A2. 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 A1, the nine columns represent these nine categories of liabilities, corresponding with the right hand liability side of the Aggregate Bank-balance sheet in Fig. 1, main document. As indicated in the first row of Table A1, 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 behavior 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.

Table A1
Balance-sheet matrix.

Balance-sheet matrix	Consumers				Firms	Firms	Government	Central	Bank(s)	Σ
	M-consumers	D-consumers	LAB-consumers	LAD-consumers	Manufacture	Services		Bank		

(*continued on next page*)

[5] The banks' income or bank fee' is the difference ('spread') between interest rate ρ_1 at the asset-side of the balance sheet and ρ_d, at the liability side.

Table A1 (*continued*)

	low income non-saving	low labour income in**D**ebted	Labour / Assets/ Bonds ≈ Financial markets	Labour/Assets/ Dividends/ Shares						
Deposits	$+ D_M$	$+ D_D$	$+ D_{LB}$	$+ D_{LS}$	$+ D_{firms}$		$+ D_{gov}$		-D	0
Bank Loans / mortgages		$-BL_D$			$- BL_{firms}$		$- BL_{gov}$		+ BL	0
Bank equity									- E + E	0
Accounts receivable (bail out)							$- BL_{default}$		$+ BL_{default}$	0
Bonds			$+ B_{cons}$				- B	$+ B_{repurchase}$	+ H - H	0
Shares				+ Shares	- Shares					0
Tangible capital					$+ K_M$	$+K_S$				+ K
Net worth	$- NW_M$	$-NW_D$	$- NW_{LAB}$	$- NW_{LAD}$	$-NW_{Mfirm}$	$-NW_{Sfirm}$	$- NW_{Gov}$		0	- K
∑	0	0	0	0	0	0	0		0	0

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:

Table A2
Transactions-flow matrix.

Transactions-flow matrix	**Consumers**				**Firms**	**Firms**	**Government**	**Central**	**Bank (s)**
	M-consumers	**D-consumers**	**LAB-consumers**	**LAD-consumers**	**Manufacture**	**Services**		**Bank**	
	low income non-saving	low labour income in**D**ebted	Labour / Assets / Bonds ≈ Financial markets	Labour / Assets Shares /Dividend					
Wages	$+W_m$	$+ W_D$	$+ W_{LB}$	$+ W_{LBC}$	$- W_{firms\ M}$	$- W_{firms\ S}$	$- W_{gov}$		
Consumption	$-C_m$	$- C_D$	$- C_{LB}$	$- C_{LBC}$	$+ C_M$	$+ C_S$			
Investments					$+ I_M - I_M$ $+ I_{M\ S}$	$+ I_S - I_S$ $- I_{M\ S}$			
Change in equities / shares				- Δ E	$+ \Delta E_{M+S}$				
Dividends				+ Div	$- Div_{M+S}$				
Interest on deposits		$+ \rho_d . M_D$	$+ \rho_d . M_{LAB}$	$+ \rho_d . M_{LAD}$	$+ \rho_d . M_{firms}$		$+ \rho_d . M_{gov}$		$- \rho_d . M$
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		$+ \Delta BL_D$			$+ \Delta BL_{firms}$		$+ \Delta BL_{gov}$		–
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		$‘- \Delta BL_D/mt$							0
Default on loans / mortgages		$+ f . BL_D$			$+ f . BL_{firms}$				- f . BL
Recapitilization / bail out banks							- f . BL		+ f . BL
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 Δ B	- 0.5 Δ B			+ Δ B		
Interest on bonds			$+ (\rho_l + 0.02) . B$				$- (\rho_l + 0.02) . B$		
Cental Bank bond purchase (QE)			+ Δ B					-Δ B	
CB Money creation CBDC							+ CBDC	-CBDC	

A.3.1. Banks

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 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. In case of bank resolution (by the government) the same amount is restored through recapitalization $f.BL_{recap}$ of the bank(s), which might include as well nationalizations and other costs; (a part of the recapitalization is paid back to the government later).

The bank acquires interest paid over the bank loan $\rho.BL_{mc}$ and pays interest over the deposit $\rho.M_{dep}$.

$$\rho\, BL_{mc} + f.BL_{recap} + BL_{repay} = \rho M_{dep} + f.BL_{default} + BL_{mc} \tag{18}$$

A.3.2. Firms

Firms pay wages to workers and receive money on their deposits by selling products to consumers and the government. Profits are calculated as sales revenues and interest income from money on their deposits 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 to the LAD-consumers, accounted for on their respective bank deposits. 50% 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 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 not 'liquid' and not available as dividend to the LAD-consumers.

Firms transaction flows are summarized as:

$$C + I_{in} + \Delta E + \Delta BL_{firms} + \rho \mathrm{d}.M_{firms} = W_{firms} + I_{out} + Div + \rho_l\, BL_{firms} + T_{firms} \tag{19}$$

Income (at the left hand side of the equation) is derived from selling goods and services to consumers C, selling of investment goods to other firms I_{in}, shares emission ΔE, obtained Bank Loans ΔBL_{firms} and interest on deposits $\rho\ d.M_{firms}$.

Expenditures (right hand side) are wages W, dividend on shares Div, interest on bank loans ρ.BL and Taxes T. 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.

A.3.3. Households / Consumers

The four categories of consumers receive income from labor in the form of wages and pay income taxes and VAT. The M (Minimum-) consumers have no debt, but neither a significant bank deposit.

Only the category of D-consumers has debts: their net income equals wage income minus taxation, minus interest dependent costs of housing (repay and interest costs of mortgages). The remianing income is assumed to be entirely spent on consumption. D-consumer transactions thus are given by:

$$W_D + \Delta LF_D = C_D + \rho_l\, LF_D + \rho_l\, BL_D + \Delta BL_D/maturity + T \tag{20}$$

with W wages and ΔLF the increase in lent Loanable Funds, C consumption, ρ LF and ρ BL the interest payments on Loanable Funds and Bank Loans, ΔBL/maturity the yearly repay on the Bank Loan (mortgage) and T taxation.

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

$$W_{LABD} + \Delta BFL_{asset} + \rho_b B_{LAB} + div_{LAD} = C_{LABD} + \Delta B_{LAB} + \Delta E_{LAD} + T \tag{21}$$

with W wages, ΔBFL_{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 (LAD) and T taxation. In the model ΔBFL_{asset} is received as the (bank intermediated) continuous repay of the overall mortgages.

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

$$C = a + b_i.F_{net} + b_w.M_{liq\ ass}\ (\mathrm{M/yr}) \tag{22}$$

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.

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, van Nieuwerburgh, & Verdelhan, 2013) and has been set at 0.03. 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.)

A.3.4. Government

Government is financed by the sum of taxation (T), the emission of Bonds $B_{emitted}$, additional bank loans ΔBL_{gov} and money creation MC_{gov}. The taxes are raised on the basis of gross consumer/worker wages and of net profit of firms i.e. after dividend payments. Besides, a Value Added Tax is applied on the consumption flow.

Government spending is given by the sum of Wages, Government consumption C_{gov}, Social payments, the interest on Bonds (ρ B) and Bank loans (ρ BL). Social payments are assumed to be a function of both wages of M-consumers and the level of unemployment. As a consequence, government social benefits increase when unemployment rises. 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 $f.BL_{recap}$. The overall government income and spending thus is given by:

$$T + B_{emitted} + \Delta\ BL_{gov} + MC_{gov} = W_{gov} + C_{gov} + SocPay + \rho_b.B + \rho_{bl}.BL_{gov} + f.BL_{recap} \tag{23}$$

In case of money creation, MC_{gov} is channeled to the real economy by lowering taxes T, repaying the government debt BL_{gov} and increasing (physical, price corrected) government spending C_{gov}. These adjustments are subordinate to the primary purpose of price stability. 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 to over 90% after the crisis, as was shown in Fig. 2B-g.
- In case of financial crisis, when governments have to come to the rescue of defaulting commercial banks, 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).

A.4. Computational aspects

The ESF-model is programmed in VENSIM-PLE (Software – Ventana Systems; vensim.com). For the purpose of quality control, all computations were made using the very same model version and computer-code. The system responses to individual parameters were assessed by imposing stepwise changes in the respective parameters to the very same model in the stationary state.

General

The manuscript has not been published and is not under consideration for publication elsewhere. We have no conflicts of interest to disclose, and all illustrations used in this paper are free of charge. No third-party material is used, or it is referenced.

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