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Sustainable economic policies: exploring the effects of sustainability-linked money creation

Augustin Sersiron[1], Jézabel Couppey Soubeyran[2], Thomas Lagoarde-Ségot[3]

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[1] Institut catholique de Paris
[2] Université Paris 1 Panthéon-Sorbonne, Chaire Energie et Prospérité, Institut Veblen.
[3] KEDGE Business School, LETS, Post-Crisis Finance Network

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Augustin Sersiron
Jézabel Couppey Soubeyran
Thomas Lagoarde-Ségot[1]

ABSTRACT

This paper explores the potential contribution of Sustainability-linked Money Creation (SMC) to sustainable economic policies. After situating this policy proposal within the extant literature, we discuss its governance and lay out its macroeconomic accounting using Eurozone data. We then analyze its effects using an ecological PK-SFC framework. Our simulations suggest that, in comparison to a baseline scenario, SMC issues could potentially constitute an anti-inflationary, counter-cyclical green transition policy, that increases biomimetic resilience and contains income and wealth inequalities. We finally discuss the policy implications, as well as the limitations of our findings.

KEYWORDS: SDG finance, stock-flow consistent modeling, Central banking, sustainability-linked money creation

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[1] Corresponding author. Email: thomas.lagoardesegot@kedgebs.com. We thank Dominique Plihon, Jacques Mazier, Renaud du Tertre and the Energy and Prosperity research Chair (Fondation du Risque) for organizing the macroeconomic modeling seminar of June 13th, 2024. Thomas Lagoarde-Ségot thanks Yannis Dafermos, Luis Reyes-Ortiz, and Edwin Le Héron for their comments on earlier versions of Philia 1.0.

1. *Introduction*

In the aftermath of the 2008 crisis, Central Banks were *de facto* turned from mere guardians of price stability (Honohan and Conell, 1997) into the lifeboats of the banking and monetary system. Floor systems and 'unconventional' quantitative easing were deployed at a global scale, and used again during the COVID-19 pandemic.

This emerging paradigm for Central Banking has, however, sparked several criticisms amongst economists. Noting that the availability of reserves is no indicator of the availability of credit, many authors underlined that these policies were ill-suited to fix European economies plagued with endemically low levels of aggregate demand (Martin et al., 2016, Lavoie and Fiebiger, 2018)[2]. Other authors, noting that Central Banks were, in fact, subsidizing banking sector's profits, underlined the anti-distributive aspect of such policies (Sersiron, 2021; De Grauwe and Ji, 2023; Dufrêne, 2023)[3].

However, these policy experiments have also led several authors to call Central Banks to play a promotional role in financing the UN Sustainable Development Goals (SDG) (Rochon et al., 2022; Van't Klooster, 2020; Schoenmaker, 2021; Dafermos et al. 2021; Deyris, 2023; Dikau and Volz, 2021). Given that Central Banks stand at the apex of the monetary system aligning the economy with the SDGs might also require to adjust Central Banks mandates, reporting practices and policies accordingly. At an institutional level, this view is shared the United Nations, which has called for "*bold policy innovations*" to "*aggressively scale up sustainable development goals (SDG) financing"* (UN, 2023).

Recently, a series of books (Grandjean and Dufrêne, 2020, Dufrêne, 2023, Couppey-Soubeyran *et. al* (2024)) and a doctoral thesis (Sersiron, 2021) have contributed to carve out a new participative channel for monetary policy, which we call 'Sustainability-linked money creation' (SMC)[4]. Its main objective is to create a solvent demand for otherwise insolvent green projects, thereby financing the public and common good components of the SDGs. Importantly, these new deposits would substitute, rather than top-up, brown investment projects. Banks would deposit the corresponding new reserve assets in a specific Central Bank account carrying a new zero rate. An independent public body would monitor the impact of the process on the SDGs, and credit Central Bank with a new non fungible asset measuring the impact of SMC issues on sustainability – in line with triple materiality (financial, natural and social) reporting practices. According to its proponents, SMC would update monetary policy to the "*age of sustainable development*" (Sachs, 2022) and would improve monetary sovereignty by enhancing the public's 'ethical trust' in monetary institutions (Aglietta and Orléan, 2002).

However, to the best of our knowledge, the analytical implications of this policy proposal have not yet been explored analytically. This is the intended contribution of this paper.

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[2] The availability of reserves is no indicator of the availability of credit, or banks' willingness to lend, which depends on productive bets and expected demand. From that perspective, the belief that QE could provide stimulus to the economy was akin to '*monetarism in reverse gear'* (Lavoie and Fiebiger, 2018, p. 141).

[3] In the eurozone, the Central Bank supplied debt-free reserve assets to banks through negative refinancing rate. Banks held on to these reserves (or swapped them for higher yield private sector instruments), without incurring debt to the central bank, nor creating deposits in the economy.

[4] This process was discussed in the francophone literature under various headings, such as "*monnaie écologique*", "*monnaie libre de dette*" or "*monnaie volontaire*".

We first situate SMC within the extant literature, with a particular focus on the longstanding 'debt-free money' controversy. We then describe its intersectoral balance sheet accounting using Eurozone data. We then explore its implications through simulations with Philia 1.0, an ecological post-Keynesian stock-flow consistent model[5]. In comparison to a 'brown scenario' in which no sustainable policies are implemented, SMC could potentially mitigate the negative inflationary retroaction from the ecosystem, decrease income inequalities, improve postgrowth resilience indicators, while leaving the Central Bank's equity unchanged, and decreasing the public deficit ratio. We finally discuss several areas of concerns, the limitations of our modeling framework, and the practical implications of our findings.

The remainder of this paper is structured as follows. Section 2 situates SMC within the extant literature, lays out its macroeconomic accounting and discusses its governance. Section 3 describes Philia 1.0's transaction and flow of funds matrix, as well as the main features of the steady state and brown scenario. Section 4 describes how SMC affects the model's equations and discusses our findings. Finally, section 5 brings together our conclusions.

2. Sustainability-linked monetary creation (SMC)

2.1. Links with the extant literature

The debt-free money controversy

A recent body of research discusses new prototypes for sustainable monetary policies, such as ecological risk-free assets (Lagoarde-Ségot and Revelli, 2023), the endogenization of local complementary currencies (Lucarelli and Gobi, 2016; Didier and Lagoarde-Ségot, 2023; Lagoarde-Ségot and Matthieu, 2023; Blanc, 2024), or 'postgrowth' monetary policy rules (Funalot, 2024). Sustainability-linked money creation (SMC) belongs to this literature. However, its distinctive feature is to have arisen from long standing discussions on the consequences and feasibility of 'debt-free money' policies.

Such discussions, which spurred from Irving Fisher's contribution (1935) to the 'Chicago Plan', have experienced a revival in the aftermath of the 2008 crisis, when various authors and institutions such as the International Monetary Fund (Benes and Kumhof, 2012), Adair Turner (2015), and several scholars (Muellbauer, 2014, Buiter, 2014; Martin, Monnet, Ragot, 2021; Buetzer, 2022) considered 'helicopter money' issues as a new stimulus policy. The development of the blockchain technology, and the deployment of central bank digital currencies (CBDCs) experiments around the world have also contributed to placing 'debt-free money' under the spotlight [6] (Bech and Garrat, 2017; Auer and Böhme, 2020, 2021). 'Debt-free money' is also

[5] The replication code and the model appendix can be found at https://github.com/lagoarde/philia. For papers using previous version of the model, see Lagoarde-Ségot and Revelli (2023), Didier and Lagoarde-Ségot (2024), and Lagoarde-Ségot, Le Quang and Scialom (2024).

[6] CBDC experiments are underway in several countries: China's e-yuan, Sweden's e-krona, Lithuania's LBCoin, etc. On November 1, 2023, the European Central Bank launched the preparatory phase that could lead to a decision to put an e-euro into circulation (ECB, 2023). Some authors suggest that CDBCs could be used as a tool to increase financial inclusion (Omarova, 2020; Dissaux and Kalinowski, 2023), make welfare and stimulus payments to distressed firms (Ozili, 2023), and facilitate the implementation for monetary policy by reducing the infrastructural power of banks and cryptocurrencies (Cesaratto and Febrero, 2023). Others have warned against the accountability pitfalls of giving excessive powers to unelected central bankers; and highlighted the risks of destabilizing the financial system in case of a 'digital bank run' (massive transfers from bank deposits to CBDCs) (Larue *et al.,* 2020; Mersch, 2020; Lannquist and Tan, 2023).

sometimes championed by activists calling to heavily upgrade the role of Central Banks in monetary creation (i.e. narrow money, 100-per-cent reserves, full reserve banking…), or calling for the Central Bank to adopt new QE by providing free deposits (or alternatively green bonds at a zero interest rate) to tackle the ecological transition. Finally, calls for a 'post-debt' monetary regime are sometimes endorsed by ecological economists, based on the view that interest-based credit creation system creates an unsustainable growth imperative, and should therefore be eliminated if the economy is to remain within planetary boundaries (Douthwaite, 2006; Farley *et al.*, 2013).

In recent years, debt-free money has sparked a vibrant controversy amongst progressive economists. One the one hand, the case against debt free money creation was developed by several prominent post-Keynesian authors. Through a detailed analysis of intersectoral balance sheets, Lavoie (2019) concluded that 'debt-free money' was in fact equivalent to a fiscal deficit, in which the Treasuries issued by the government reflux on the balance sheet of the Central Bank[7]. Unless the Central Bank keeps a zero interest rate forever, it follows that debt-free money is not 'debt free', and its marginal impact on the fiscal balance can be proxied by the deposit facility rate to T-bond rate spread (Lavoie and Fiebieger, 2018). It follows that 'debt-free money' would come short of opening a much needed new policy space for emerging market economies which, due to international capital mobility and the unequal global monetary order, are subject to tight fiscal constraints (Ponsot, 2016; Paula, Fritz and Prates, 2017; Prates, 2020). In the case of developed countries, fully rolling back endogenous money creation by banks would create new concerns, including an unpredictable development of shadow banking, a nullification of automatic fiscal stabilizers, and giving an excessive role of the central bank over democratic decision-making (Fulwiler, 2013; Fontana and Sawyer, 2016). Finally, from a planetary boundaries' perspective, the careful accounting distinction between debt stocks and flows of interest payments operated by Lavoie (2014) indicates that debt-based money does not create a growth imperative *per se* provided that the stock of debt remains constant. This argument has been validated by several PK-SFC models showing that positive interest payments are in fact compatible with a stationary economy (Jackson and Victor, 2016; Cahen-Fourot and Lavoie, 2020).

In response, debt-free money advocates have put forth a series of counterarguments. First, they underlined that much of the critique leveled at debt-free money creation hypothesizes a full consolidation of the balance sheets of the Central Bank and the Treasury. While both institutions do belong to the public sector[8], there is, to this date, no empirical record of a full transfer of Central Bank losses to Treasury, including during the recent period where several Central Bank

[7] Consolidating the balance sheet of the Treasury and the Central Bank into one government balance sheet is in fact common practice throughout various theoretical frameworks of economic analysis (Tymoigne, 2024).

[8] While many countries do maintain separate accounts for the Treasury and the Central Bank, in most cases, « *The treasury will often also have responsibility for ownership of the central bank. It needs to manage the corporate relationship with the central bank, which will be either directly owned by the government, or set up as some form of statutory corporation under law, but clearly part of the public sector. (…) Other major policy issues with budgetary implications might be the possible need to recapitalize the central bank or to compensate it for the costs of running monetary policy. Normally, it would be preferable to maintain some separation between this ownership role and the interactions related to debt and cash management policy or to the treasury's role as a customer of the central bank, possibly transferring the ownership function elsewhere in the ministry of finance* » (Pessoa and Williams, 2012, p. 11).

experienced losses because of their unconventional monetary policies (Monnet, 2024). In fact, according to the Bank of International Settlement, a Central Bank can operate with negative equity, without having to be bailed out by its shareholder (Archer and Moser-Boehm, 2013; Bell and al., 2023). While transfer of excessive Central Bank losses to the Treasury cannot be ruled out, the latter is not automatic and we have no evidence to this date of the speed and rate at which it might occur.

Second, debt-free money creation is in fact nothing new. In recent years, asset purchases by the Central Bank from non-banking institutions has involved the creation of debt-free deposits through the 'acquisitive' monetary creation channel. Monetary policies involving negative refinancing rates have also involved the creation of 'debt-free' reserve assets for the banking sector (Couppey-Soubeyran *et. al*, 2024). To some extent, the rolling out of public debt by the Treasury performs a similar monetary function by turning public debt into a permanent stock of 'outside' deposits (Bridonneau, 2024). Finally, insight from the money circuit theory (MCT) suggests that 'debt-free money' is in fact, a fixture of a monetary economy: the stock of deposits permanently left in the economy as a counterpart of defaulted loans, is de facto 'debt-free', and facilitates the monetization of profits (Graziani, 2003).

Third, several ecological economists have pointed out that while interest-based money is theoretically compatible with a stationary economy, in practice, it embeds economic agents in a financial 'Logos' incompatible with strong sustainability (Walter, 2020). Using ten historical case studies, Hartley and Kallis (2021) showed that compound interest creates a *de-facto* addiction to economic growth since lending interest in cases of no or low growth is socially problematic due to the accumulation of debts and rising inequalities. Critical finance studies have also shown that interest-bearing financial models reify the power of shareholders, leaving no space for alternative definitions of sustainable value (Lagoarde-Ségot and Paranque, 2018). Perhaps not surprisingly, the rise of 'green finance' has failed to fill the sustainable finance gap, and fuels systemic risk, income and wealth inequalities (Jäger and Diwok, 2023).

Beyond the debt-free money controversy: double materiality in Central Bank accounting

SMC builds upon the above controversy by connecting 'debt free money' with the adaptation of Central Bank accounting to double materiality practices. Regardless of the consolidation of the Treasury and the Central Bank's account, measuring the impact of 'debt-free money' on the Central Bank would require, ex-ante, to properly measure the accounting items featured in its balance sheet. A large body of research and practice in ecological accounting, however, argues that current accounting practices provide biased signals to economic agents as they rest upon a truncated view of capital (Richard and Rambaud, 2022). Implicit here is the acknowledgement that the definition of capital is "*not a technical or an economic problem but reflects a cosmology, an imaginary* (Castoriadis, 1999, p.3).

Recently, the United Nations introduced ecosystem natural capital accounting (ENCA) by the UN, with the ecosystem capability unit (ECU) serving as a new unit of account, in line with strong sustainability principles (UN, 2021). Other efforts in this direction include ecological accounting experiments with public and private bodies showing that profit and losses can in fact be redefined to account for the conservation costs of the three types of liabilities (nature, society and equity capital), not only financial liabilities (CARE, 2024).

In turn, adjusting the balance sheet of the Central Bank to ecological accounting principles opens new avenues for sustainable monetary policies. If successful in creating a positive social and ecological impact, policies such as SMC could, in fact, have a positive impact on a Central Banks' untruncated, ecological-adjusted balance sheet.

2.2. Governance and macroeconomic accounting

SMC entails a new targeted and democratically governed channel for money creation. It serves to accelerate the substitution of brown productive assets by green productive assets in all sectors of the economy, in line with the SDG transformation. Importantly, SMC is not designed to provide stimulus to the economy, but it is conceived as a tool for sustainable structural change.

In the spirit of Couppey-Soubeyran *et al.* (2024), a sound SMC governance structure shall operate a clear separation of powers, by establishing three separate public mandates: (i) a mandate to select which SDG projects should be financed through SMCs, (ii) a mandate to determine the quantity of SMC issues, and (iii) a mandate to spend SMCs in the economy.

SMC issues could thus be broken down into the following steps:

Step 1: Territorial stakeholders (including members of parliament, other representatives of civil society (trade unions, associations, etc.) and scientists (climate-scientists, economists, sociologists, etc.) identify and budget projects eligible to SMC issues. Eligible projects must cover non-profitable, green productive investment, which could substitute for a brown, profitable, productive investment and have a maximum impact on the SDGs.

Step 2: Stakeholders' recommendations are reviewed and adjusted by Parliament, in line with the State's commitment to the Paris Agreement, and are transferred to the Central Bank.

Step 3: The Central Bank's monetary policy committee decides on the volume of SMC issues, considering all the other components of its decision rule. Therefore, issuing SMC does not imply to roll out Central bank independence, but requires to formally include SDGs objectives into its mandate.

Step 4: The Central Bank credits non-banking financial institutions (e.g. *Sustainable Development Funds* with local stakeholders' governance) with new SMC. The Sustainable Development Funds finally spends SMCs in the economy.

Step 5: Following an independent review, the Central Bank books a new, non-commodifiable asset named *Contribution to the SDGs* (CSDG) measuring the effect of SMC issues on the SDGs through shadow pricing techniques, in line with double materiality practices.

Figures 1 to 3 decomposes the SMC issuing process using intersectoral balance sheets, using Eurozone data, and including Sustainable Development Funds into the monetary financial institutions sector. In line with recent estimates of the sustainable finance gap, these figures calibrate SMC issues to 3.5% of GDP[9].

[9] Current estimates point to a shortfall of 2 to 5 GDP points in private and public investment (Pisani-Ferry and Mahfouz, 2023; Gourmand, 2024). These estimates are generally narrow, limited to the climate transition without considering biodiversity losses and the social aspects of the transition. A World Bank study estimated the SDG finance gap to 7.2% of GDP in low and middle-income countries per year to build SDG related infrastructure (Doumbia and Lauridsen, 2019). On the basis of these orders of magnitude, which make no clear distinction

Through *Sustainable Development Funds*, the Central Bank allocates new subsidies to firms (paid on their current accounts) by issuing new liabilities in the form of SMC, which shows up as a non-remunerated asset in banks' balance sheets. These SMC assets are balanced with new deposit liabilities, which the firm sector holds as net assets.

Following an independent review, the Central Bank books a new, non-commodifiable asset named *Contribution to the SDGs* (CSDG). The latter measures the extent to which SMC has contributed to the preservation of natural and social capital, in line with the Paris Agreements and ecological accounting principles (Richard and Rambaud, 2021). The crediting of CSDGs testifies the effective contribution of SMC issues to the SDGs.

Depending on the projects, the rate at which SMC convert into CSDG might exceed one (in which case, other things equal, the net equity of the Central Bank shall increase), be lower than one (in which case the net equity of the Central Bank shall decrease) or equal to one (in which case the net equity of the Central Bank shall remain constant).

For the sake of simplicity, these figures assume a one-to-one conversion rate: one monetary unit of SMC creation leads to the preservation of one 'shadow' monetary unit of account of natural and social capital. In this case, inspection of the figure shows that the closing balance sheets of all sectors - but that of the Treasury - balloons, while only the net wealth of the firm sector increases.

INSERT FIGURE 1 TO 3 ABOUT HERE

3. Insight from an ecological stock-flow consistent macroeconomic model

3.1. PK-SFC modeling

PK-SFC modeling, as pioneered by the seminal work of Godley and Lavoie (2012), stands out as an appropriate tool with which to analyze the impact of SMC on the economy. *First*, SFC models realistically integrate the monetary financial and real sides of the economy in an endogenous money framework. SFC models realistically portray banks as credit creators hierarchically embedded in a monetary system (which also includes central banks, investment funds and securities dealers). Except for the government's outside money creation, in PK-SFC models, the money stock is hence entirely tied to expectations: banks are partially accommodative and supply financial liabilities in response to entrepreneurial demand, in interaction with endogenous real and monetary variables. Finally, Central Banks have no direct control over the money supply and take pricing decisions by setting the interbank rate - which they implement through the purchase and sale of public and private assets. Whenever the Central Bank credits the banking sector with excess reserves (for instance through quantitative easing policies) this has no direct impact on the stock of banking deposits and other monetary aggregates. This post-Keynesian representation of the monetary system provides a realistic background with which to study the effects of SMCs.

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between profitable and unprofitable investments, one could reasonably assume that unprofitable green investments that cannot be financed in the conventional way amount to around 3.5% of GDP.

Second, in SFC models all behavioral equations are nested in a double-entry accounting matrix derived from the National Income and Product Account (NIPA). This ensures a coherent stock-flow integration of income and financial accounting, in which each sectoral balance sheet features a buffer that serves to reconcile expected with realized outcomes. All stocks of assets, liabilities, and flows of income and spending hence take consistent and meaningful values. By virtue of this watertight and realistic accounting constraint, a stock-flow consistent model produces a stable pattern of causal events, over both the short and long term, regardless of the value of parameters. This shall lay ground for a thorough interpretation of the full implications of SMC issues on income, stocks of debts and liabilities, in a fully traceable setting.

Third, SFC models achieve economic closure through stock fluctuations rather than through price adjustment (except for financial markets), the underlying micro-level hypothesis being that agents adopt a procedural rationality inspired by Simon (1986). Any mistaken expectations generate an undesired accumulation or depletion of stocks that signals a required change in behavior, economic agents thus behaving "*like good statisticians*" (Chow, 2011) that predict future observations by updating the sample's mean[10]. SFC models shall thus permit to analyze the response of agents to the introduction of SMCs with credible behavioral foundations.

3.2. The model's structure

Accounting structure

Our simulations are based on a new version of Philia 1.0, an ecological PK-SFC model developed iteratively in a series of recent papers[11] (Lagoarde-Ségot and Revelli, 2023; Lagoarde-Ségot and Didier, 2023; Lagoarde-Ségot, Le Quang and Scialom, 2023). Table 1 shows Philia 1.0's simplified transactions and flow of funds matrix. The model features two categories of households. Working households earn their income as wages and redistributed profits from social businesses; and keep their savings as sight and deposit accounts. Rentier households earn income in the form of interest and investment fund dividends; and keep their savings as deposits and investment fund shares.

The model features three categories of firms: public sector firms (whose balance sheet is amalgamated with that of the government), social businesses (owned by working households, finance rationed, and financing their investment through retained earnings and loans only), and listed firms (owned by investment funds and financing their investment through retained earnings, loans, bonds, commercial paper and equity issues). Financial sector instruments include reserves, sight deposits, savings deposits, loans, bonds, commercial paper, equities, investment fund shares and Treasuries. Investment funds invest the 'loanable funds' provided by rentier households in corporate equities, Treasuries, hold deposits, and own the equity of the banking sector.

Finally, the Central Bank operates a refinancing desk, a deposit facility, and holds a portfolio of Treasuries. It repurchases risky asset portfolios through quantitative easing whenever banks

[10] The adaptive expectations hypothesis was shown experimentally to outperform the rational expectations hypothesis even in a highly volatile financial market environment (Afrouzi *et al.*, 2023) and is increasingly used in macro modeling, including in mainstream models (Dizioli and Wang, 2023).

[11] The technical appendix and replication code are available at https://github.com/lagoarde/philia.

fail to hit their capital adequacy ratio. Its net profits are distributed to the Treasury, which also owns its equity to maintain accounting closure. In line with post-Keynesian principles, this implies that Central Bank profits and losses are immediately transferred to the Treasury.
The model also features an ecosystemic block adapted from Carnevali *et al.* (2021). Due to space savings constraint the material and energy balance, the physical stock flow matrix, the behavioural equations, and the 48 accounting closure tests are included in an online technical appendix.

Table 1 Simplified transaction matrix

	Households		Government			SME/SSE		Listed firms		Banks		Central Bank		Investment funds	
	Working	Rentiers	Treasury	Public sector											
				Current	Capital	Current	Capital	Current	Capital	Current	Capital	Current	Capital	Current	Capital
Final consumption	$-C_w$	$-C_k$		$+C_p$		$+C_c$		$+C_k$							
Public expenditure			$-G$			$+G_c$		$+G_k$							
Taxes	$-T_w$	$-T_k$	$+T$			$-T_c$		$-T_k$							
Public deficit			$-DEF_g$		$+DEF_g$										
Investment				$+I_p$	$-I_p$	$+I_c$	$-I_c$	$+I_k$	$-I_k$						
Depreciation				$-DA_p$	$+DA_p$	$-DA_c$	$+DA_c$	$-DA_k$	$+DA_k$						
Wages	$+W$			$-W_p$		$-W_c$		$-W_k$							
Entrepreneurial profits	$+FD_c$			$-F_p$	$+F_p$	$-F_c$	$+FU_c$	$-F_k$	$+FU_k$					$+Div_k$	
Bank profits										$-F_b$				$+F_b$	
Central bank profits			$+F_{Cb}$									$-F_{Cb}$			
Investment fund profits		$+F_s$												$-F_s$	
Interest paid on :															
Central bank refinancing										$-r_a A$		$+r_a A$			
Private debt instruments						$-r_{d,c} D_c$		$-r_{d,k} D_k$		$+rD$					
Bank deposits	$+i_d M_w$	$+i_d M_m$								$-i_d M$				$+i_d M_s$	
Central bank portfolio						$-r_{d,c} R_c$		$-r_{d,k} R_k$				$+rR$			
Mandatory reserves										$+r_h H$		$-r_h H$			
Excess reserves										$+r_e H_e$		$-r_e H_e$			
Treasuries			$-r_g GB$							$+r_g GB_b$		$+r_g GB_{bc}$		$+r_g GB_s$	
Δ STOCKS															
Central bank loans											$+\Delta A$		$-\Delta A$		
Private debt instruments							$+\Delta D_C$		$+\Delta D_k$		$-\Delta D$				
Bank deposits	$-\Delta M_w$	$-\Delta M_k$									$+\Delta M$				$-\Delta M_s$
Reserve currency	$-\Delta H_w$	$-\Delta H_k$									$-\Delta H_b$		$+\Delta H$		
Equities									$+\Delta E_{k,s}$						$-\Delta E_{k,d}$
Investment fund shares		$-\Delta S$													$+\Delta S$
Central bank asset purchases											$+\Delta RA$		$-\Delta RA$		
Treasuries					$+\Delta GB$						$-\Delta GB_b$		$-\Delta GB_{cb}$		$-\Delta GB_s$
Bank equity											$-\Delta BE$				$+\Delta BE$
Central bank equity			$+\Delta K_{cb}$										$-\Delta K_{cb}$		

Note: For the sake of clarity, this matrix consolidates bank loans, private bonds and commercial paper (and their respective interest rates) into the 'private debt instruments' accounting item. This matrix also ignores the brown and green taxonomy which applies to financial instruments and productive assets. Please refer to https://github.com/lagoarde/philia for a full description of the model and replication codes.

3.3 The stationary state

Using the Broyden algorithm, the model stabilizes after 30 iterations and reaches its most stable stationary state after 150 periods. The real GDP growth rate then strictly equates 0.06% for 120 periods, and then gradually increases to 0.14% from period 288 until period 500 (which is the end of our simulation horizon). We conduct our simulations in the most stable interval (from period 150 to 210). This interval depicts a quasi-stationary, artificial economy, with a size and structure like that of the eurozone – assuming away net exports (which represents 1.75% of eurozone GDP) (Eurostat, 2024).

As shown in figure 4, real GDP stands at about $23,000 trillion PPP at the beginning of the stationary scenario. Consumption accounts for 52% of real GDP, public spending for 26% and private investment for 21%. The wage share stands at around 60% of GDP and the public deficit stands at 5.7%, then declines slowly to 5% over the reference period. Corporate debt (loans, corporate bonds and commercial paper) represents 65% of corporate financing, self-financing 30%, and listed share issues 5%. Net dividend payments as a percentage of GDP are around 4%. Banks modulate their purchases of Treasuries to maintain the liquidity ratio at 100% and the leverage ratio lies safely above the 12% regulatory target.

As shown in figure 5, the Treasury market clears without Central Bank intervention, with the banking sector purchasing an increasing share of fresh government bond issues. The balance sheet of the investment funds sector displays a growing appetite for equities with the share of Treasuries and deposits decreasing slightly over time. Finally, the steady state features a standard risk and term structure of interest rates, with the three monetary rates (the Central Bank's deposit facility, mandatory reserve deposit and main refinancing operations rate) standing at the bottom, then the rate on Treasuries, the deposit rate, the lending rates, and finally riskier market instrument rates (commercial paper and corporate bonds carrying a higher rate[12].

Under the baseline scenario, income and wealth inequalities increase over time, which is a typical stylized fact for finance-led economies (Szymborska, 2022). The ratio between the financial wealth of rentier and working households increases by 0.8 points (from 6.9% to 7.7%). The ratio between the income of rentiers and working households increases by 0.2 points (from 6.5% to 6.7%).

Likewise, the economy's fitness for evolution score decreases from 0.79 to 0.73, i.e. below the 'window of resilience' (0.85) identified in Ulanowicz et al. (2009). Indeed, 'throughput' develops faster than 'resilience', which implies that money does not circulate evenly, with monetary strangleholds (located in the rentier and financial sector) undermining the economy's ability to absorb unexpected shocks (figure 6).

3.4. The 'brownflation' scenario

Starting from the steady state (period 150), we activate the ecosystemic equations under a 'brownflation scenario'. We calibrate the ecological block assuming that the green trajectory of the rest of the world mirrors that of our artificial economy. Our main results are shown in figure 4. Total CO2 emissions reach 37 billion tons in period 162 (the amount observed in 2023 for the world economy (Global Carbon Budget data). At the end of the simulation, global

[12] Indeed loans rate tend indeed to be lower than corporate bond rates in the Eurozone (see https://www.ecb.europa.eu/press/financial-stability-publications/fsr/focus/2023/html/ecb.fsrbox202305_06~d859e24a8a.en.html)

temperatures have risen by 3 degrees. Together with the scarcity of material and energy resources, rising temperatures increase the value of the ecological destruction function from 0.02 to 0.25 at the end of the simulation (figure 4).

One distinctive feature of Philia 1.0 is that these ecosystemic events retroact to the economy mainly by generating inflationary biases (with annual inflation reaching 0.15% at the end of the simulation). We shall thus discuss the model's inflationary mechanisms in more detail. As shown in equation (1.1) to (1.4), inflation (π) stems from three factors: adaptive inflation expectations (π^a) and two idiosyncratic shocks. The first idiosyncratic shock (π^e) arises from observed ecological damages (d_{t-1}), material (dep_{m-1}) and energy depletion (dep_{t-1}) . The second idiosyncratic shock (π^f) arises from firms' mark-up pricing over wage costs ($\frac{\Delta WB_{-1}}{Y_{-1}}$).

$$\pi = \pi^a + \pi^e + \pi^f \tag{1.1}$$

$$\pi^a = \pi_{-1} + o_1(\pi_{-1} - \pi^a_{-1}) \tag{1.2}$$
$$\pi^e = o_2(dep_{l-1} + dep_{m-1} + d_{t-1}) \tag{1.3}$$
$$\pi^f = o_3\left(\frac{\Delta WB_{-1}}{Y_{-1}}\right) \tag{1.4}$$

In turn, inflationary biases generate macroeconomic welfare losses, mainly through its anti-redistributive effects, which decrease aggregate demand (Lavoie, 2022). In fact, during labour negotiations, employee representatives target a wage bill (WB^a) equal to the product of the wage share negotiated during the last round of negotiations ($\iota_{wb,-1}$) and real GDP (equation (2.1).

$$WB^a = \iota_{wb,-1}\,\hat{Y} \tag{2.1}$$

Due to inflation, nominal GDP exceeds real GDP (i.e. $Y > \hat{Y}$), so that the ex-ante wage share (ι^a_{wb}) - computed as a ratio of the agreed wage bill (WB^a) and nominal output (Y) - comes short of trade unions' wage share target (i.e. $\iota^a_{wb} < \iota_{wb,-1}$) (equation (2.2)).

$$\iota^a_{wb} = \frac{WB^a}{Y} \tag{2.2}$$

While trade unions adjust the wage share target ($\overline{\iota^T_{wb}}$) accordingly (equation 2.3), the actual wage share, however, only adjusts partially due to the bargaining power of corporate executives (Ω_{wb}) (equation (2.4)). Inflation thus decreases the wage share, and ultimately affects the nominal wage bill (WB) (equation (2.5)).

$$\iota^T_{wb} = \iota_{wb,-1} + \bar{\bar{\iota}}(\iota_{wb,-1} - \iota^a_{wb}) \tag{2.3}$$

$$\iota_{wb} = \iota^a_{wb} + (\iota^T_{wb} - \iota^a_{wb})\Omega_{wb} \tag{2.4}$$

$$WB = \iota_{wb} Y \tag{2.5}$$

As shown in figure 7, the real wage share shrinks from 60% in the baseline scenario to 47% at the end of the brown scenario. This generates a drop in working household income, aggregate demand, and GDP. Ecosystemic shocks thus retroact through a post-Keynesian setting by which inflation decreases the consumption of working households and GDP.
Inflation also widens the gap between nominal and real GDP, with the GDP deflator reaching 106 at the end of the simulation (versus 100 in the steady-state scenario).

Finally, climate change also affects household behavior. Households react to climate destructions (d_{t-1}) by building up precautionary savings, which decreases their propensity to draw out of their accumulated savings (α_2) (equation (3)). The latter parameter decreases from 0.2 to 0.195 during the simulation.

$$\alpha_2 = \frac{\alpha_{2,-1}}{(1 + \vartheta d_{t-1})} \tag{3}$$

INSERT FIGURE 7 ABOUT HERE

Overall, by the end of the simulation period, nominal GDP is 18.5% lower than in the baseline scenario, and real GDP is 22.5% lower than in the baseline scenario. This order of magnitude is aligned with recent estimates of the cost of global warming (Kotz et al., 2024; Waidelich et al., 2024). One should also note that the reported costs account for automatic stabilizers. Indeed, under the brown scenario public deficit increases by 4 points (from 5% in the baseline scenario to 9%).

INSERT FIGURE 8 ABOUT HERE

At the end of the simulation, income and wealth inequality has also increased (figure 8), with the ratio between rentiers' and workers' income gaining 6 points (from 6.5% to around 13%), and the ratio between the financial wealth of rentiers and that of workers gaining 2 points (from 7% to 9%). Inspection of the postgrowth metrics confirms this trend: the fitness for evolution score has decreased by 10%, mostly due to a lower resilience. Indeed, the income and wealth of working households, which depends mostly upon wages, is the most affected under the brown scenario. Rentiers, who only receive financial income expressed as a fixed percent of a nominal target (dividends paid by listed companies, banks and interest payments from investment funds) appear more protected from the direct effect inflation. These analytical results are thus aligned with recent estimates showing that the costs of climate disruption are borne by households with the lowest incomes and wealth (Waidelich et al., 2024).

4. The SMC scenario

4.1. Transmission mechanisms

SMC issues and calibration

We calibrate annual issues (smc) at 3.5% of annual nominal GDP throughout the entire simulation. Contribution to the SDGs ($CSDG$) is defined as a fraction (τ) of the accumulated stock of SMC. In the scenario we let $\tau = 1$. Annual issues are spent by the SDG fund to the social firm (smc_c), listed firm (smc_k) and public sector (smc_p), with parameters σ_i set so that $smc - \sum_{i=s,k,c} smc_i = 0$. We let $\sigma_c = \sigma_k = 33\%$ ((4.1) to (4.6)).

$$smc = 3.5\% Y_{-1} \tag{4.1}$$
$$SMC = SMC_{-1} + smc \tag{4.2}$$
$$CSDG = \tau SMC \tag{4.3}$$
$$smc_c = \sigma_c smc \tag{4.4}$$
$$smc_k = \sigma_k smc \tag{4.5}$$
$$smc_p = [1 - (\sigma_k + \sigma_s)] smc \tag{4.6}$$

Impact on private sector investment

SMC-financed green project must substitute for an equivalent brown project and leave the overall investment spending constant. However, the model differentiates the notional demand for green and brown investment ($I_d = I_{d,g} + I_{d,b}$) from the effective demand ($I_s = I_{s,g} + I_{s,b}$). As shown in (5.1) to (5.4), SMC issues will top up the 'effective' demand for green investment of both social sector and listed firms; and reduces the 'notional' demand for brown investment accordingly[13].

$$I_{s,c,g} = l_{s,c,g} + P_c ret_c \frac{I_{d,c,g}}{I_{d,c}} + smc_c \tag{5.1}$$

$$I_{s,k,g} = f_{s,k,g} + (P_k ret_k + e_{s,k}) \frac{I_{d,k,g}}{I_{d,k}} + smc_k \tag{5.2}$$

$$I_{d,c,b} = I_{d,c} - I_{d,c,g} - smc_c \tag{5.3}$$

$$I_{d,k,b} = I_{d,k} - I_{d,k,g} - smc_k \tag{5.4}$$

SMC issues shall also impact the green structure of notional demand for both categories of firms. Social and listed firms' baseline notional demand for green investment ($I_{d,c,g}, I_{d,k,g}$) is given as a proportion (ω_{c1}, ω_{k1}) of the corresponding total notional investment demand ($I_{d,c}, I_{d,k}$). The baseline demand is then modulated by adaptation efforts to ecosystemic destructions ($ad \times d_{t-1}$), by the brown interest rate spread, and by public green investment pulling the private sector green investment demand ($\frac{\Delta I_{s,p,g}}{I_{s,p,g-1}}$) (Mazzucato, 2018; Carnevali *et al.*, 2021). SMC issues will thus contribute to greening the structure of investment demand by changing entrepreneurial expectations (6.1) and (6.2). The overall volume of investment demand ($I_{d,k}, I_{d,c}$) depends, however, on entrepreneurial expectations and the partial accelerator model.

$$I_{d,k,g} = \omega_{k1} I_{d,k} \left(1 + ad \times d_{t-1} + \frac{\Delta I s_{s,p,g}}{I_{s,p,-1}} + \omega_{k2} \times \left(i_{l,k,b} - i_{l,k,g} \right) + \omega_{k3} smc_k \right) \tag{6.1}$$

$$I_{d,c,g} = \omega_{c1} I_{d,c} \left(1 + ad \times d_{t-1} + \frac{\Delta I s_{s,p,g}}{I_{s,p,-1}} + \omega_{c2} \times \left(i_{l,c,b} - i_{l,c,g} \right) + \omega_{c3} smc_c \right) \tag{6.2}$$

Impact on public sector investment

Sovereign monetary system establish no difference between the notional and effective demand for public investment (Nersisyan and Wray, 2024) (7.1)[14]. Therefore, the effective public demand for green capital goods ($I_{d,p,g}$) is given as the sum of a discretionary fraction ($\overline{g_{k2}}$) of the total demand for public investment ($I_{d,p}$) and the SMC flows allocated to public sector firms (smc_p) (7.2). Public firms' demand for brown investment ($I_{d,p,b}$) is determined through accounting closure (7.3). These equations ensure that the effective demand for public investment ($I_{s,p}$) is unchanged.

[13] In (5), ($l_{s,c,g}$) is the supply of green credit to social firms. ($f_{s,k,g}$) is the supply of debt finance to listed firms. ($e_{s,k}$) is the annual flow of equity issues. (P) represents net profits and (ret) is the retention rate.

[14] The total demand for public investment ($I_{d,p}$) is discussed in section 11 of the technical appendix (https://github.com/lagoarde/philia)

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$$I_{s,p} = I_{d,p,g} + I_{d,p,b} \quad (7.1)$$
$$I_{d,p,g} = \overline{g_{k2}} I_{d,p} + smc_p \quad (7.2)$$
$$I_{d,p,b} = I_{d,p} - I_{d,p,g} \quad (7.3)$$

The budget constraint of the Treasury (government securities issues gb_s) is given in (8), where government spending includes direct spending in the private sector (G), investment expenses of public-sector firms ($I_{s,g}$), and interest payment to Treasuries holders ($i_g GB_{s,-1}$)). Government revenues include total taxes (T), public sector firms' profits (P_p), debt-free money flows to public sector firms (smc_p), as well as central bank profit (F_{cb}) and equity revaluation (ΔK_{cb}).

$$gb_s = Max\left(\left(G + (I_{s,p} - smc_p) + i_g GB_{s,-1}\right) - \left(T + P_p + F_{cb} + \Delta K_{cb}\right); 0\right) \quad (8)$$

Impact on banks and the Central Bank

SMC issues are credited to a special bank's reserve account at the Central Bank with zero rate. In equation (9), the accumulation of such reserves will decrease the demand for advances ($A_{d,b}$) at the Central Bank, where ($H_{d,m}$) are mandatory requirements and ($H_{s,qe}$) reserves obtained through the sale of risky assets to the Central Bank. Given that SMC reserves do not carry interest payments, they have no direct impact on the banking sector's income statement. From the perspective of banks, SMC emissions are thus akin to the emission of new deposits liabilities, fully backed by free reserves carrying a zero rate.

$$A_{d,b} = \left(H_{d,m} - H_{s,qe} - SMC\right) \quad (9)$$

The counterpart of the flow of Central Bank's total reserve liabilities (h) includes loans to the banking sector ($\Delta A_{d,b}$), asset repurchase programs financed through quantitative easing (Δqe_s), additional demand for circulating cash ($\Delta H_{s,h}$), and SMC issues (smc) (10.1) It accumulates in a stock (H) (10.2). The Central Bank's equity (K_{cb}) is given by the gap between its assets (which includes reserve loans to the banking sector ($A_{d,b}$), portfolio of repurchased assets (RA) and net contribution to the SDGs ($CSDG$)) and its total reserve liabilities (H) (10.3).

$$h = \Delta A_{d,b} + \Delta qe_s + \Delta H_{s,h} + smc \quad (10.1)$$
$$H = H_{-1} + h \quad (10.2)$$
$$K_{cb} = \left(A_{d,b} + RA + CSDG\right) - H \quad (10.3)$$

The Central Bank's profit (F_{cb}) has two components: the spread between the interest earned on the repurchased asset portfolio (rRA) and that paid on excess reserve deposits ($i_{df} H_{s,qe,-1}$), and the spread between the interest earned on reserve loans ($i_{rf} A_{s,b,-1}$) and that paid on mandatory reserve deposits ($i_e H_{d,m,-1}$) (11). Given that the Central Bank neither pays interest on SMC deposits, nor earn income on its CSDG assets, SMC issues has no direct impact on its profits. However, as per (9) SMC may also decrease bank's demands for reserve loans ($A_{s,b}$) and hence the income drawn from such loans.

$$F_{cb} = rRA - i_{df}H_{s,qe,-1} + i_{rf}A_{s,b,-1} - i_eH_{d,m,-1} \quad (11)$$

4.2. Simulation results

4.2.1. A 'virtuous' scenario

We now discuss a 'virtuous' transition scenario under which SMC permits the switch to a less energy-intensive mode of production, limiting the rise in temperature to 2 degrees (figure 9). This scenario requires technological parameters to be calibrated so that the green transition fosters a rapid rate of technological change and a shift in the economic structure, which in turn decreases total energy consumption (figure 9).

INSERT FIGURE 9 ABOUT HERE

In this case, the inflationary retroaction of climate change vanishes, and the wage share of GDP gets back towards its reference level. Throughout the simulation, GDP is slightly higher than in the steady state (with short run effects exceeding long run ones). As a result, the public deficit ratio returns to a trajectory close to that observed in the stationary state, and inequalities get back to levels close to that of the steady state scenario.

Importantly, the economy undergoes a structural and sustainable change. As SMC increases the financing of public sector firms and social firms, the money circulated in all corners of the economy. Postgrowth resilience metrics increase, and the economy reaches the window of resilience of 0.85 (Ulanowicz *et al.*, 2009) (figure 10).

INSERT FIGURE 10 ABOUT HERE

SMC also changes both the volume and the composition of the stock of high-powered money. The latter increases sharply, without banks needing to make additional loans from the Central Bank.

As the Central Bank takes on a new leading role in the SDG transition and adapts its accounting to double materiality principles, it books corresponding CSDG assets, and both sides of its balance sheet expand massively, leaving its net wealth unchanged (since $\tau = 1$).

Finally, the composition of the money circulating in the real side of the economy changes with SMC representing about 60% of the total stock. In comparison to the brown scenario, the money stock to GDP ratio gains 3 points at the end of the simulation, with the observed gap between the two scenarios decreasing over time (figure 11).

INSERT FIGURE 11 ABOUT HERE

With the allocation of SMC to finance-rationed social firms, their debt to capital ratio decreases massively, leading to an increase in the notional and effective demand for social firm investment. Therefore, the share of social firm credit in total bank credit increases by five points during the course of the simulation. As banks' balance sheet cease to accumulate advance loans as liabilities, the equity of the banking sector's increases in comparison to both the baseline and brown scenario. The excess reserves provided through the SMC policy increases the leverage

ratio, which gains 0.03 points in comparison to the steady state scenario, as well as the liquidity coverage ratio (figure 12).

INSERT FIGURE 12 ABOUT HERE

4.2.2. Limitations and discussions

These simulations make a case for SMC in a post-Keynesian SFC modeling framework. Nonetheless, much remains to be investigated. *First*, our simulations have left aside the determination of the conversion rate between SMC issues and the CSDG assets which the Central Bank accumulates on its balance sheet (and assumed a one-to-one conversion rate). In practice, this conversion rate, however, would hinge upon assigning a shadow price to the SDGs. In addition to presenting several practical and theoretical challenges, this task would require an external auditing to ensure that the Central Bank's balance sheet represents a faithful representation of its SDG impact. This would require adjusting the institutional framework, which might be difficult given existing legal constraints (particularly in the Eurozone).

Second, SMC issues appear to decrease the banking sector's demand for refinancing loans, with the Central Bank's refinancing desk becoming redundant. This might deprive the Central Bank of a standard monetary policy tool. This may be problematic in case the context calls for a tightening of interest rates. Of course, a lower cost of reserves does not induce an increase in bank lending per se. In fact, in our simulations interest rates charged to the social firms' sector increase, as banks tighten their lending conditions in response to the increased demand for investment. However, in the presence of an exogenous shock which might necessitate a sharp increase in interest rate, the Central Bank might be short of solutions when the banking sector's demand for reserve loans is nil. Similarly, constant SMC issues appear to reduce the banking sector's appetite for Treasuries as the accumulation of excess reserves allows banks to hit their prudential ratios more easily. While our simulations suggest that SMC issues would actually expand the government's fiscal space by decreasing the deficit ratio, policy makers should be aware of potential interactions of SMC with the Treasuries markets.

The materialization of the above risks would require, however, Central bankers to take SMC issues to the extreme, in otherwise adverse market conditions. Our suggested governance framework precisely seeks to avoid such a situation, as the mandate to determine the actual volume of SMC issues belong to the Central Bank within the framework of their mandates. One could also envision technical solutions to an overflow of SMC reserves - which would need to be studied further – such as a temporary increase in the reserve ratio or demurrage of SMC reserves , which would maintain the banking sector's demand for reserve loans. All in all, our results call for additional research into the effects of SMC, and first and foremost, for a small-scale policy experiment conducted by a Central Bank.

5. Conclusions

Scaling up SDG financing would clearly require "*innovative approaches*" and "*bold policy decisions*" (UN, 2023). In this paper, we contributed to the discussion on innovative SDG finance policy tools, by focusing on sustainability-linked money creation (SMC), as put forth in the recent literature (Dufrêne and Grandjean, 2020; Sersiron, 2021; Couppey-Soubeyran and Delandre, 2021; Dufrêne, 2023; Couppey-Soubeyran *et al.*, 2024).

We first situated this new approach within the extant literature (with a specific focus on the debt-free money controversy and ecological accounting), discussed its governance framework and described its intersectoral balance sheet accounting using Eurozone data. We then explored its analytical implications by conducting simulations with Philia 1.0, an ecological Post-Keynesian stock-flow consistent model.

Our results suggested that, in comparison to a 'brown scenario' in which no sustainable policies are implemented, SMC could potentially mitigate the inflationary retroaction from the ecosystem, decrease income inequalities, improve postgrowth resilience indicators, while leaving the Central Bank's equity unchanged, and decreasing the public deficit ratio. We then discussed the potential implications our findings, and identified several avenues for future research.

To the best of our knowledge, this paper is the first attempt at analyzing SMC in an ecological PK-SFC framework. Overall, our results suggest that SMC might have a role to play in a new 'ecological policy mix'. Nonetheless, the implementation of SMC would require more research on its legal and institutional framework, on ecological accounting, and governance. We thus call for Central Banks to carry out a small-scale pilot experiment, providing a natural experiment to be studied by economists to improve sustainability policies.

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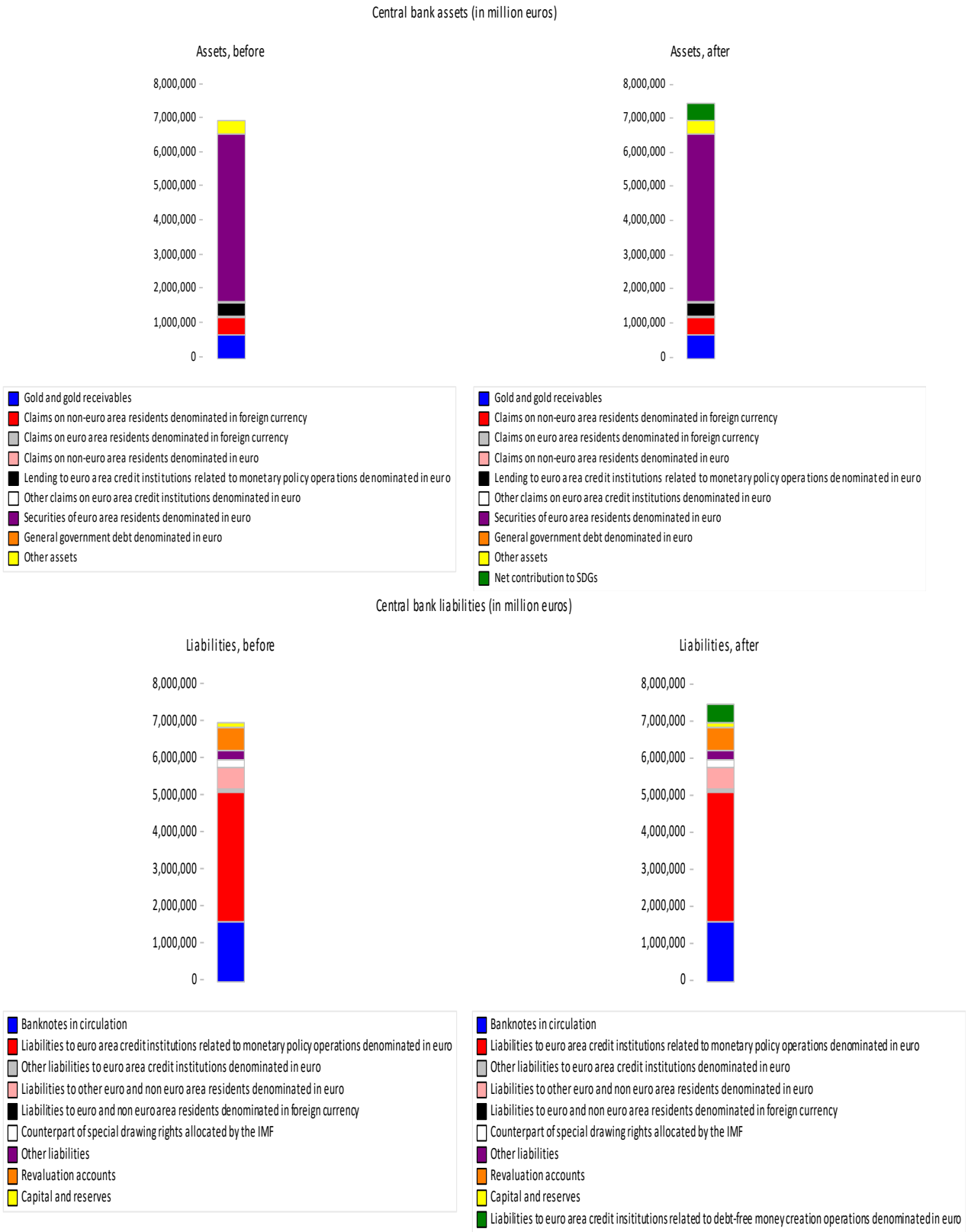
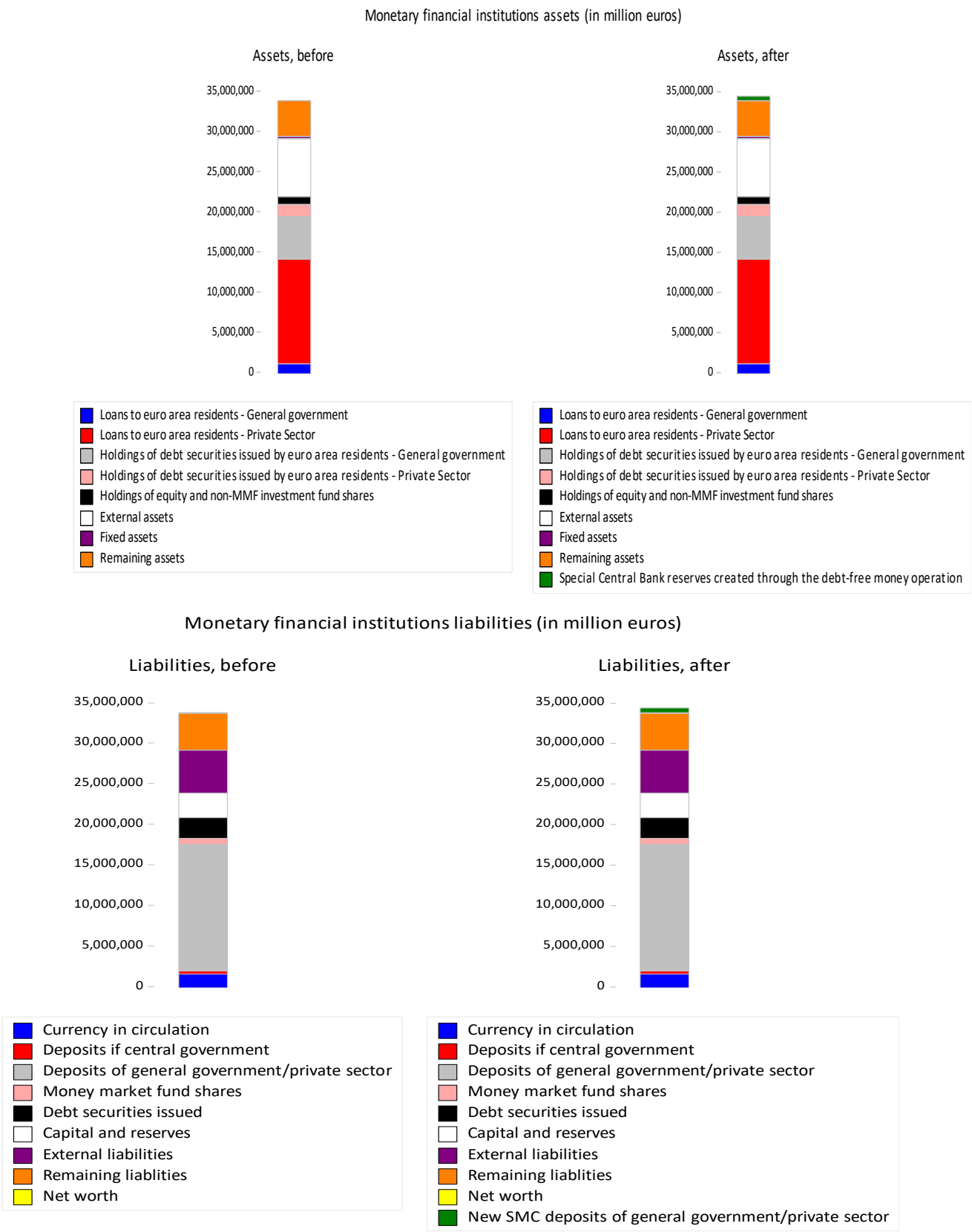
Figure 1 SMC and the balance sheet of the European Central Bank



Source: based on European Central Bank (2023) data.

Figure 2 SMC and the balance sheet of Eurosystem monetary and financial institutions



Source: based on European Central Bank (2023) data.

Figure 3 SMC and the balance sheet of Eurozone non-financial corporations

Source: based on European Central Bank data (2023)

Figure 4 The stationary state

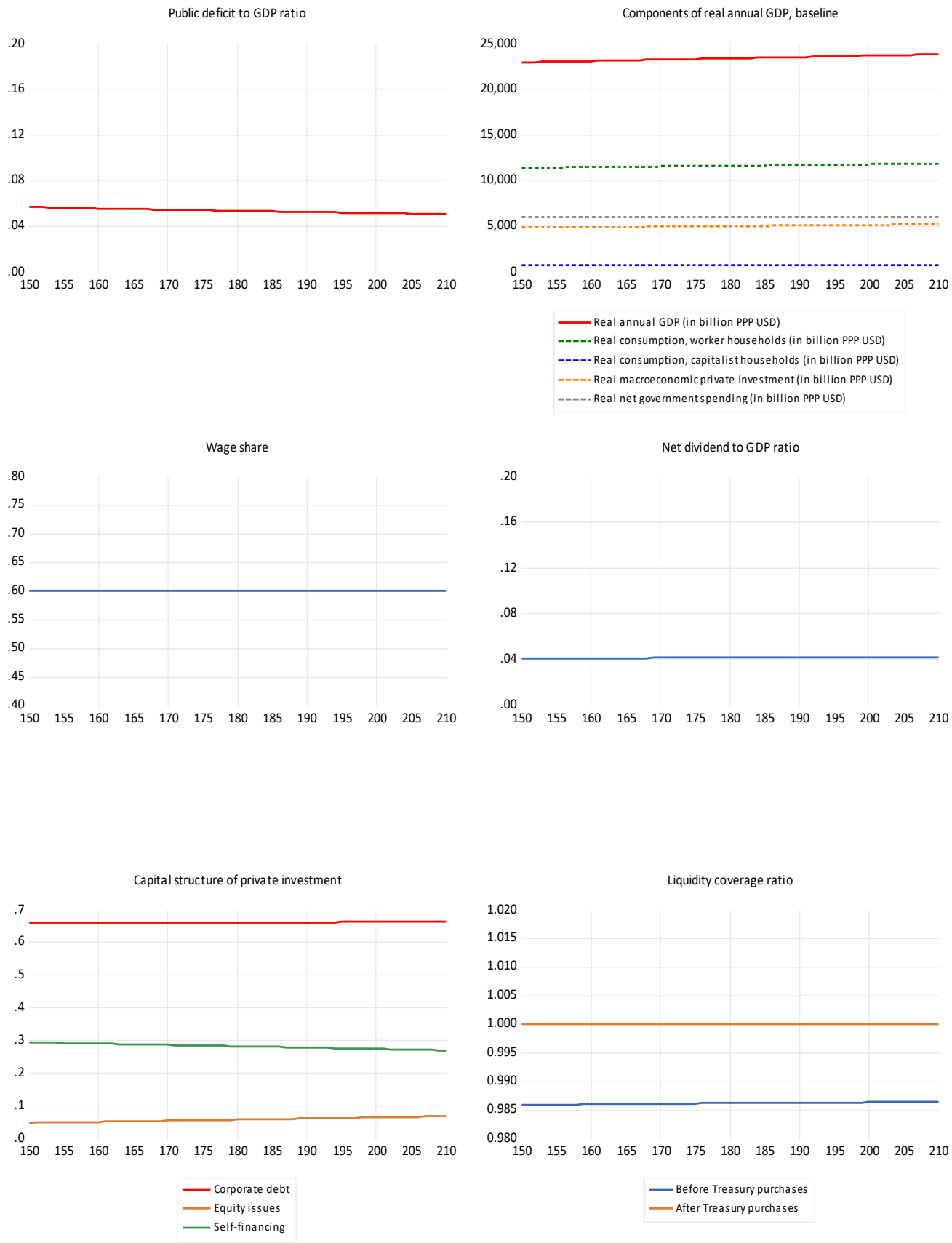


Figure 5 The stationary state (cont'd)

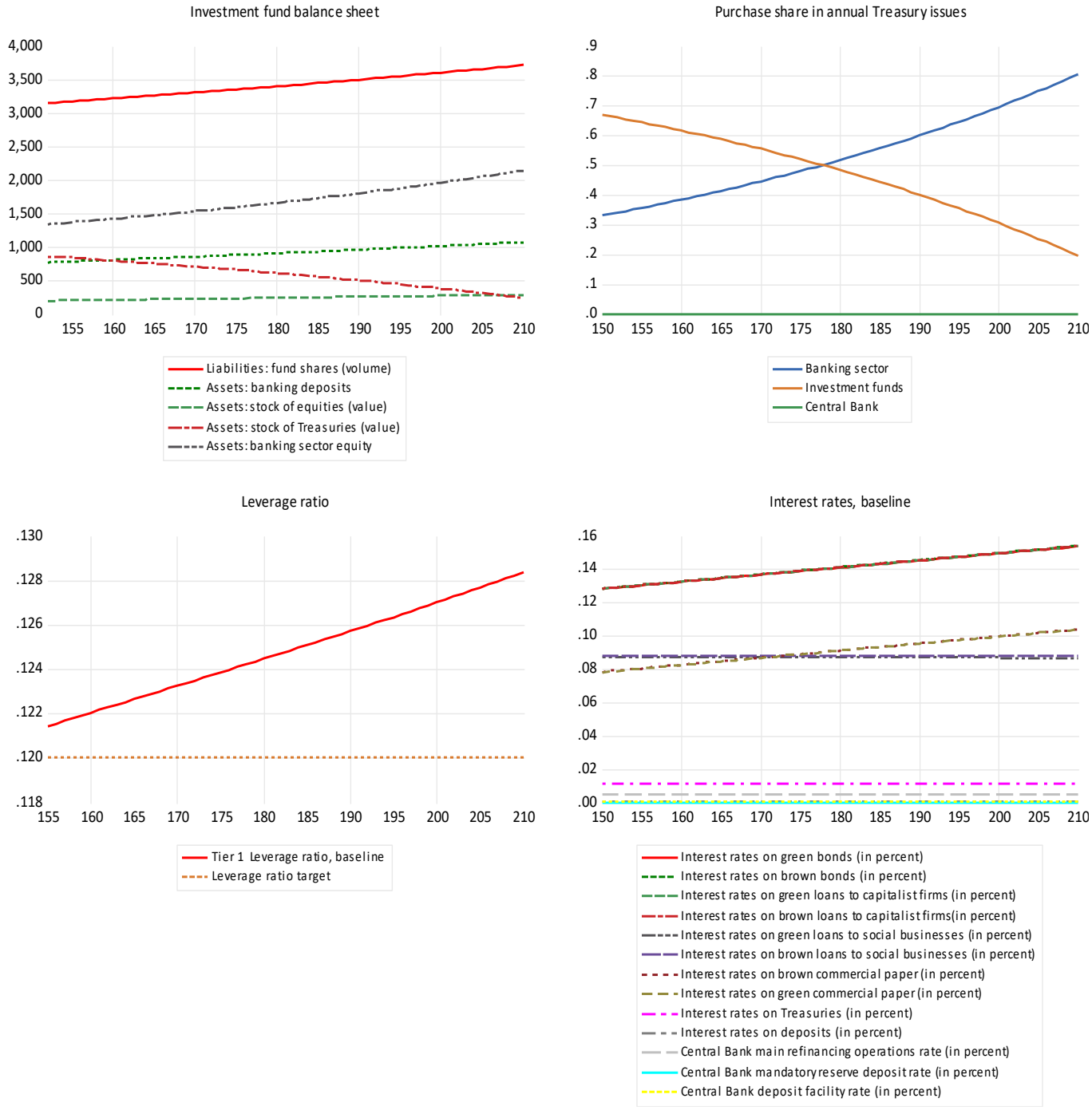


Figure 6 The stationary state (cont'd)

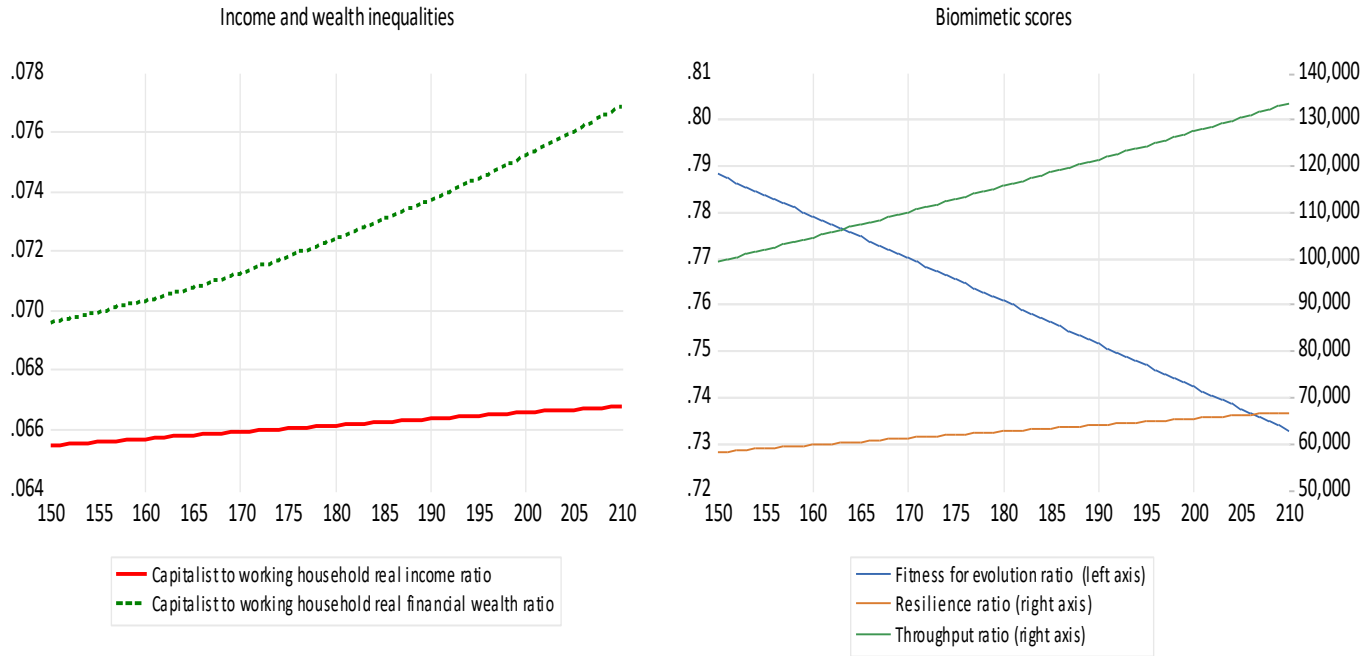


Figure 7 The 'brownflation' scenario

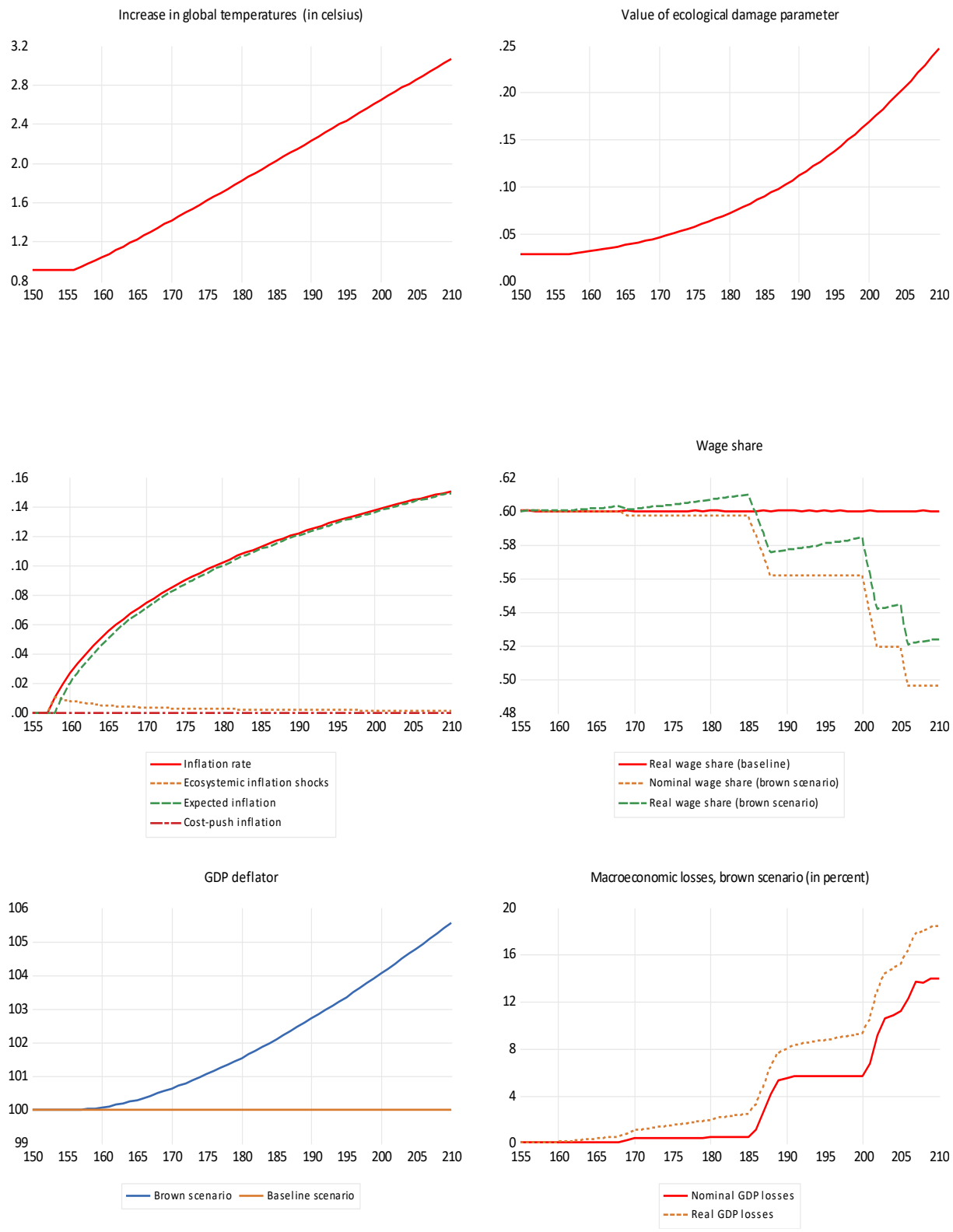


Figure 8 The 'brownflation' scenario (con'd)

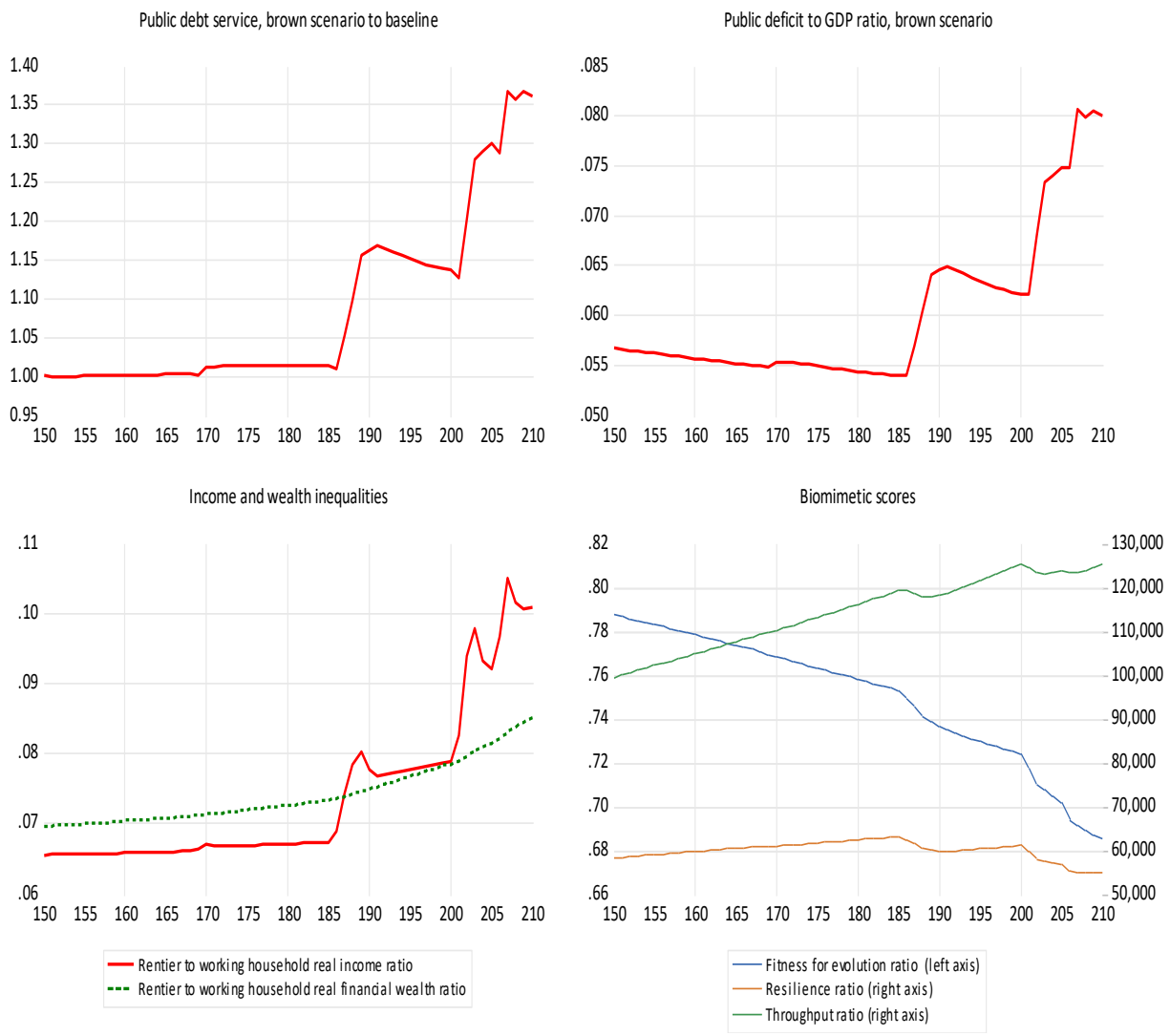


Figure 9 The SMC scenario

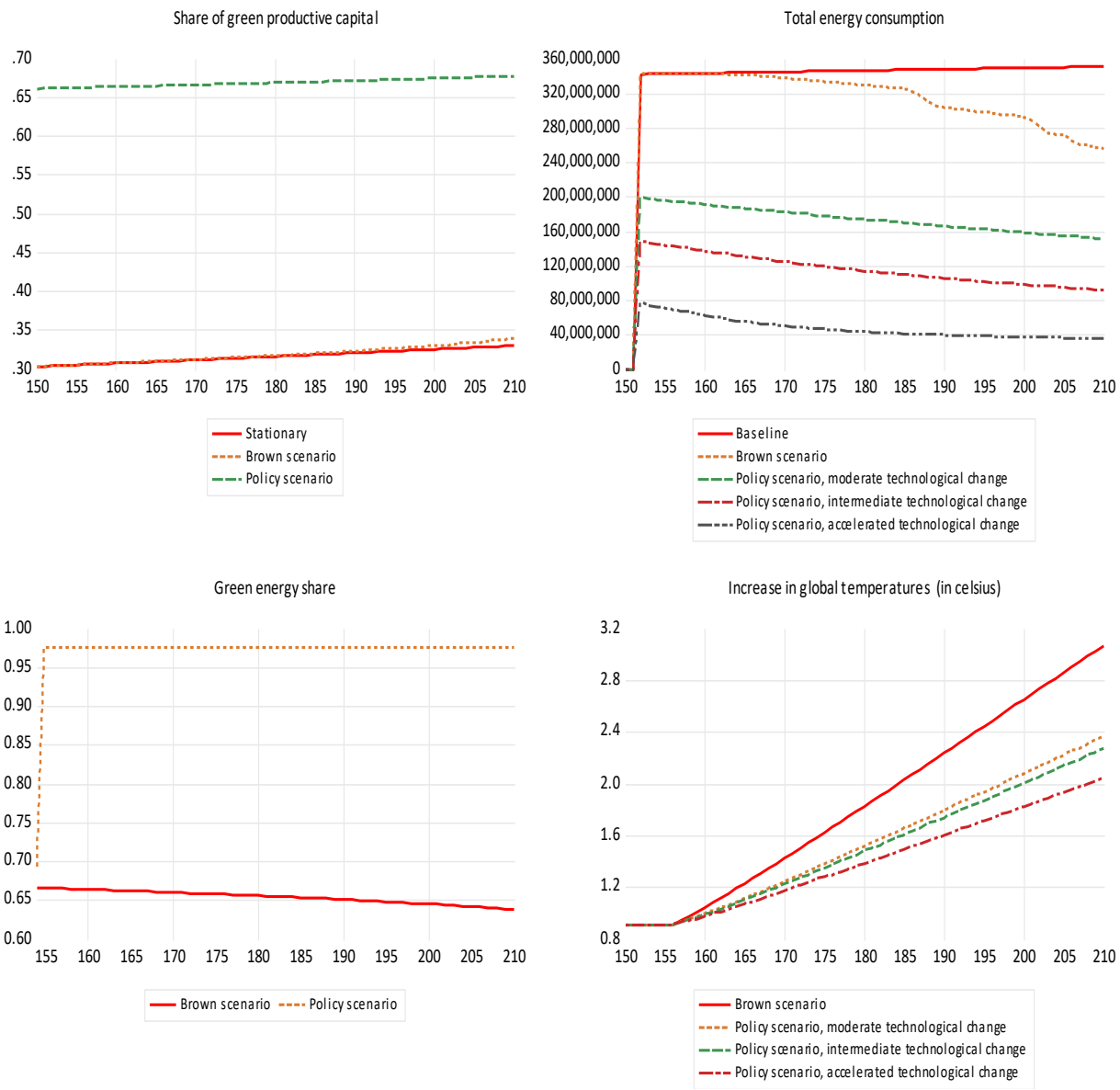


Figure 10 SMC scenario (cont'd)

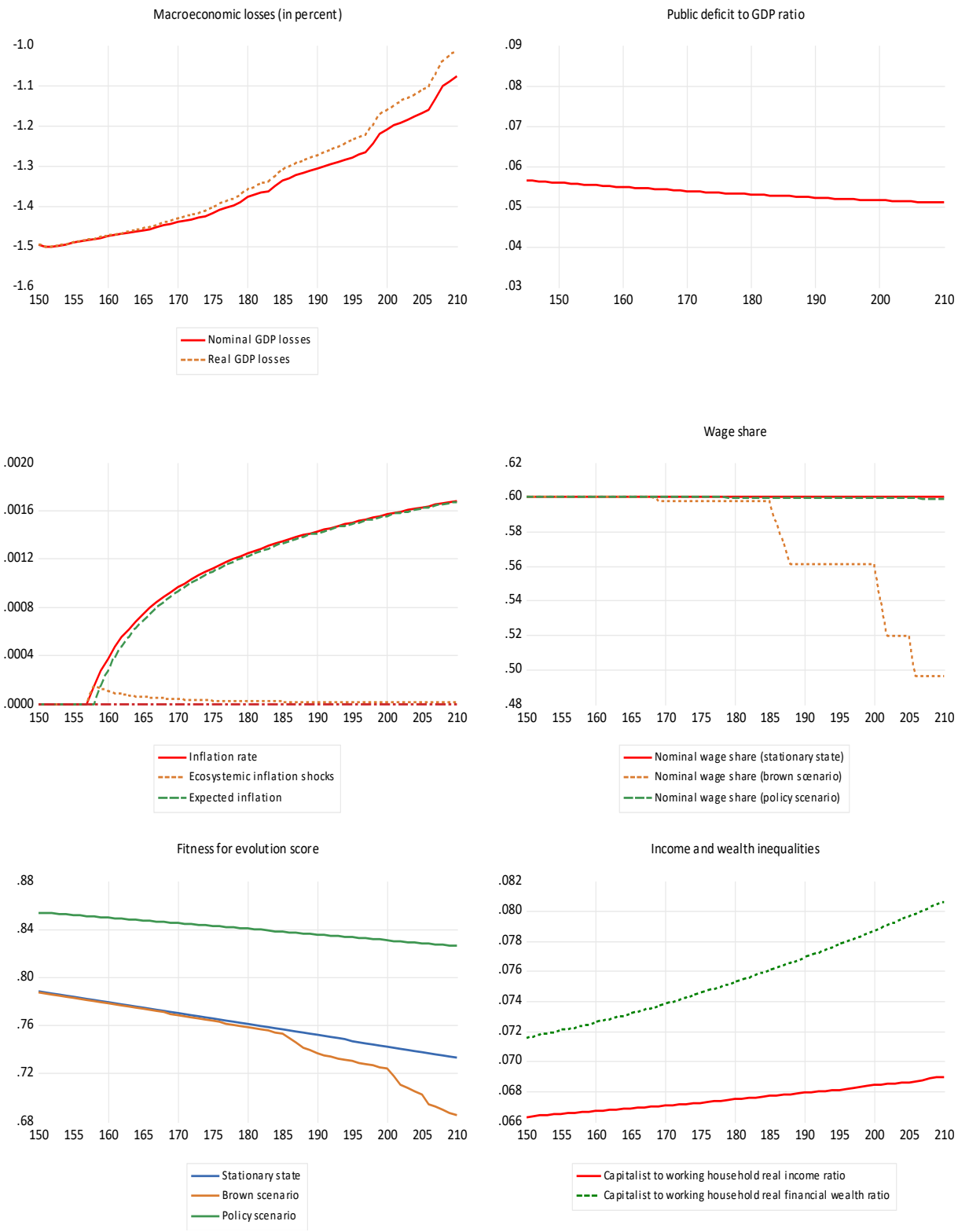


Figure 11 SMC scenario (cont'd)

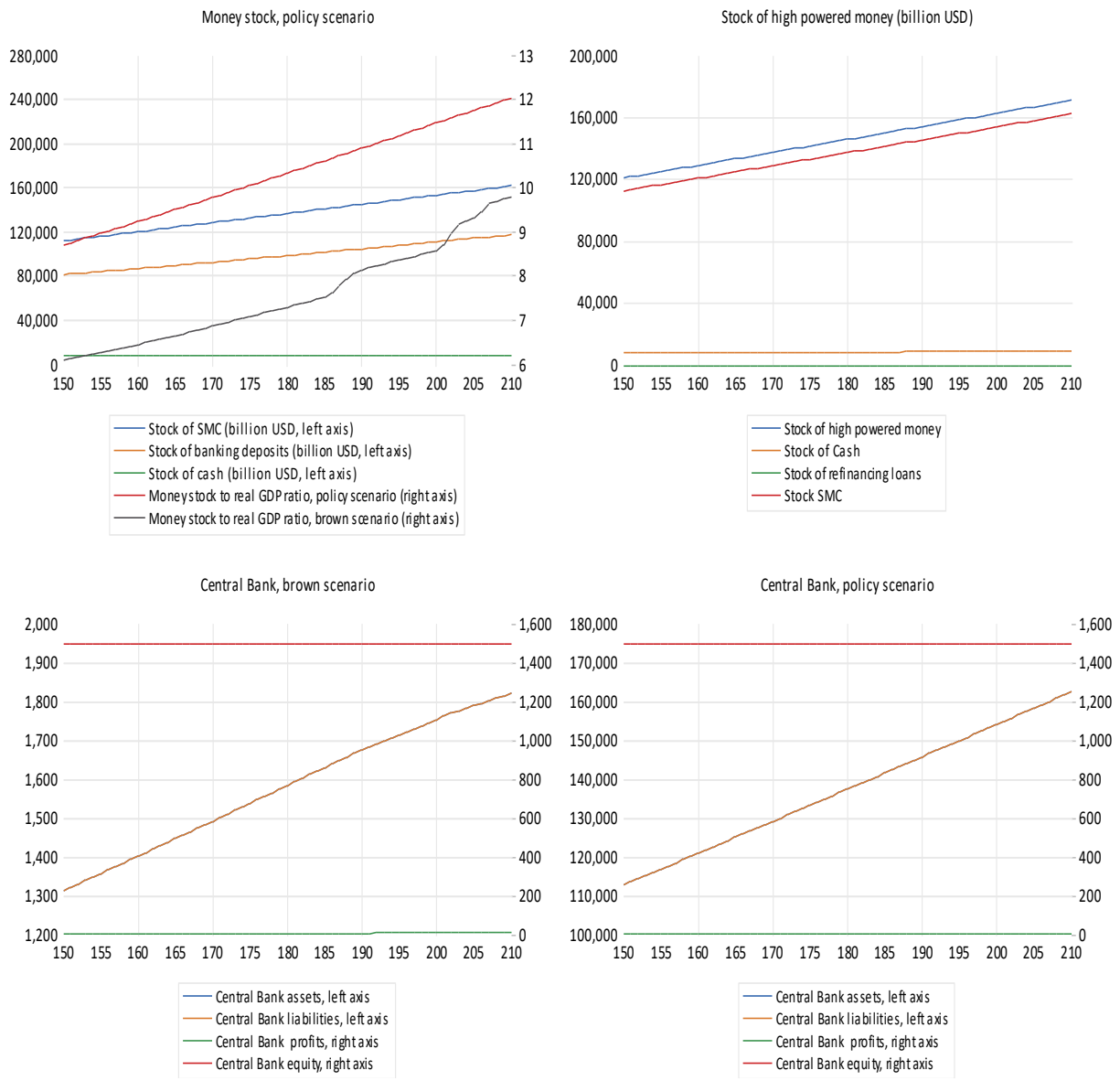
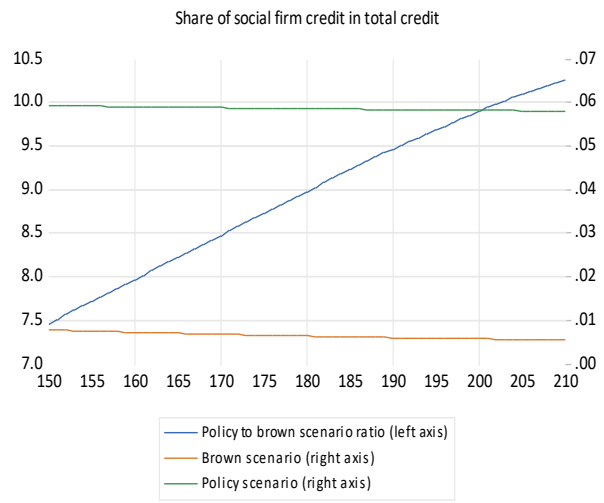
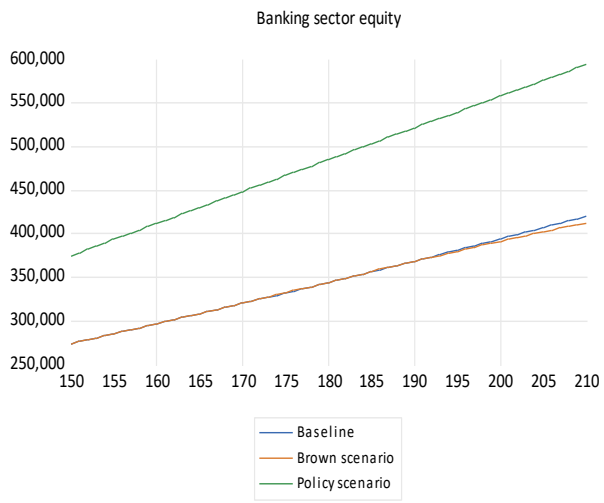
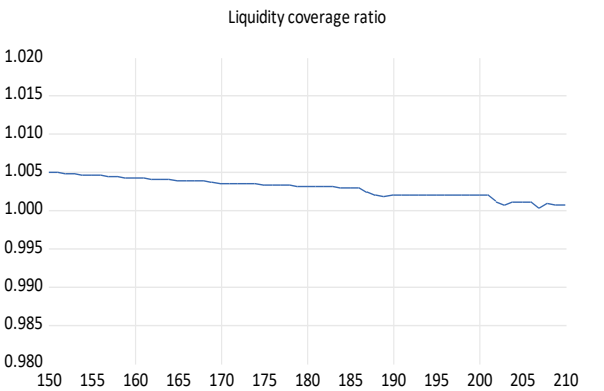
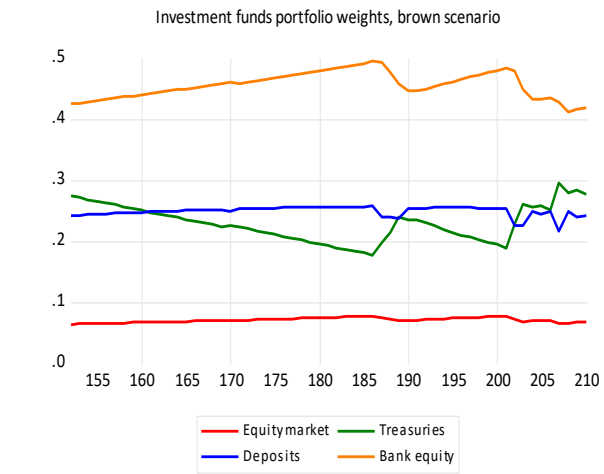


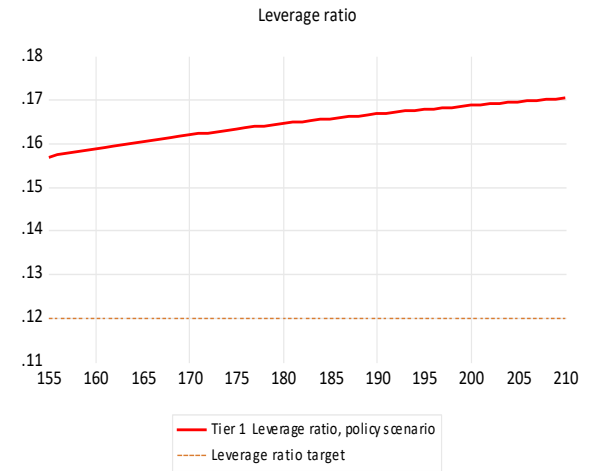
Figure 12 The SMC scenario (cont'd)

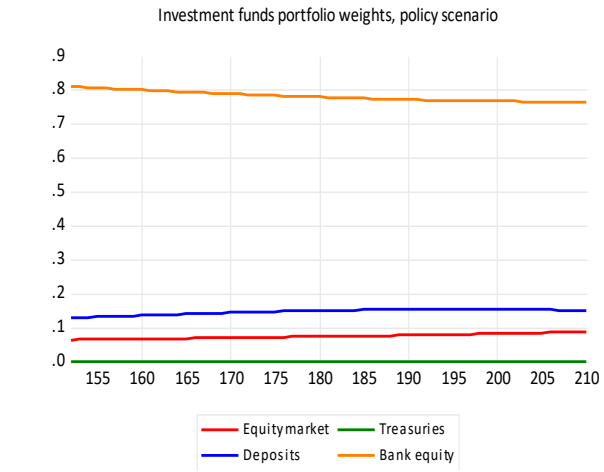

Share of social firm credit in total credit
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
.07
.06
.05
.04
.03
.02
.01
.00
150 155 160 165 170 175 180 185 190 195 200 205 210
Policy to brown scenario ratio (left axis)
Brown scenario (right axis)
Policy scenario (right axis)


Banking sector equity
600,000
550,000
500,000
450,000
400,000
350,000
300,000
250,000
150 155 160 165 170 175 180 185 190 195 200 205 210
Baseline
Brown scenario
Policy scenario


Liquidity coverage ratio
1.020
1.015
1.010
1.005
1.000
0.995
0.990
0.985
0.980
150 155 160 165 170 175 180 185 190 195 200 205 210


Investment funds portfolio weights, brown scenario
.5
.4
.3
.2
.1
.0
155 160 165 170 175 180 185 190 195 200 205 210
Equity market
Treasuries
Deposits
Bank equity


Leverage ratio
.18
.17
.16
.15
.14
.13
.12
.11
155 160 165 170 175 180 185 190 195 200 205 210
Tier 1 Leverage ratio, policy scenario
Leverage ratio target


Investment funds portfolio weights, policy scenario
.9
.8
.7
.6
.5
.4
.3
.2
.1
.0
155 160 165 170 175 180 185 190 195 200 205 210
Equity market
Treasuries
Deposits
Bank equity

Appendix A – model output
Figure A1 Welfare block output

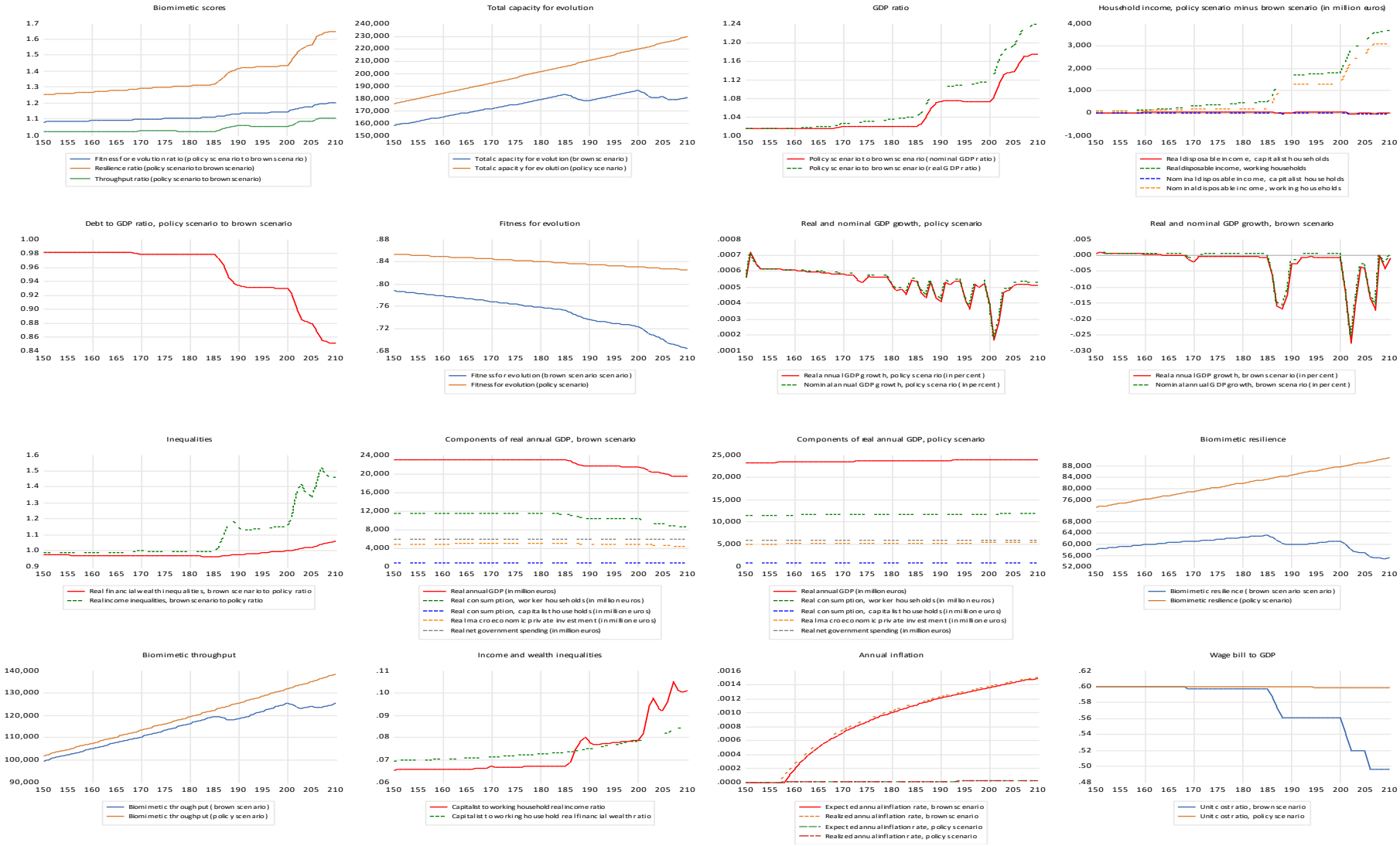


Figure A2 Investment

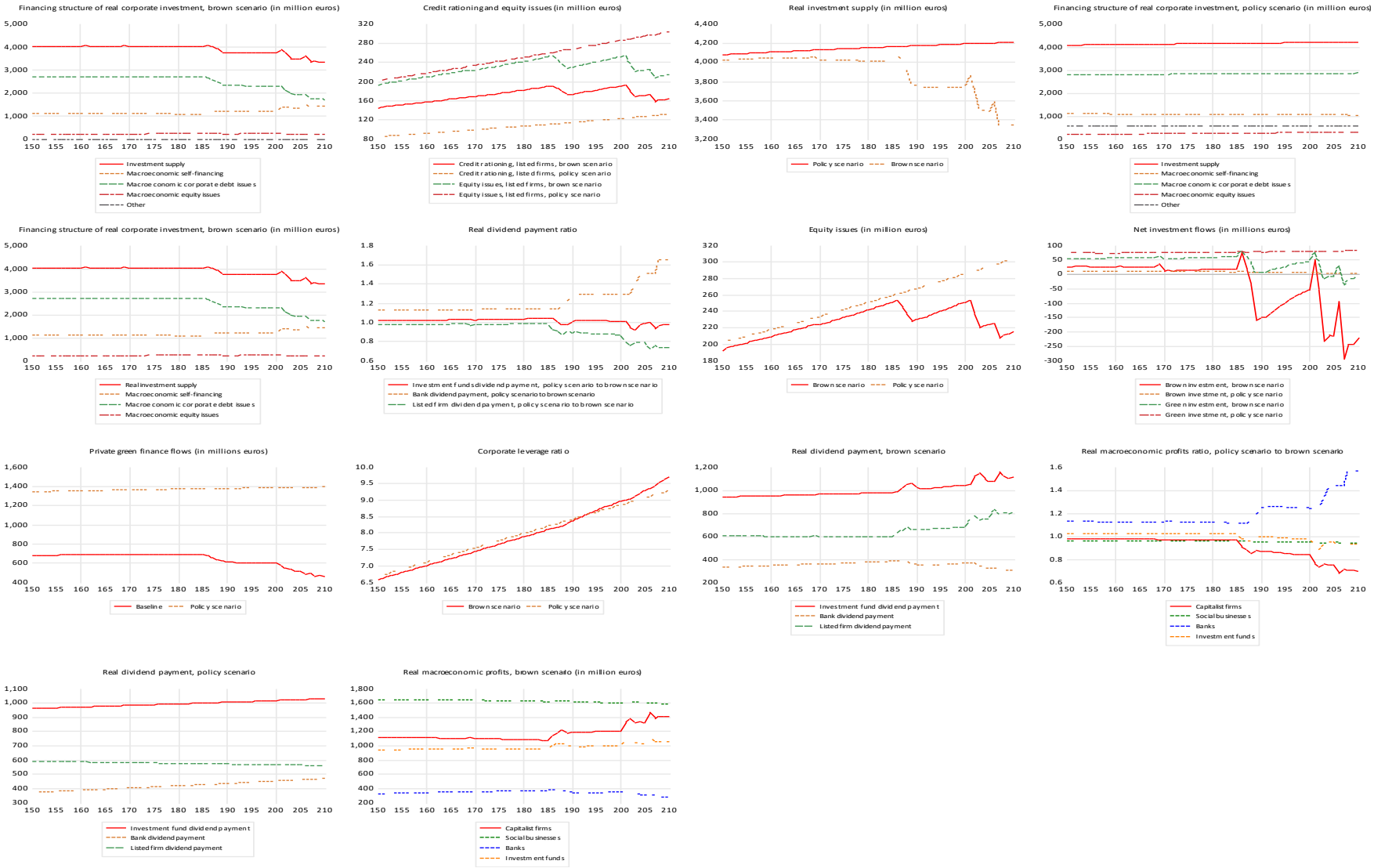


Table A3 Monetary side

Figure A4 Prudential side

Figure A5 Investment funds

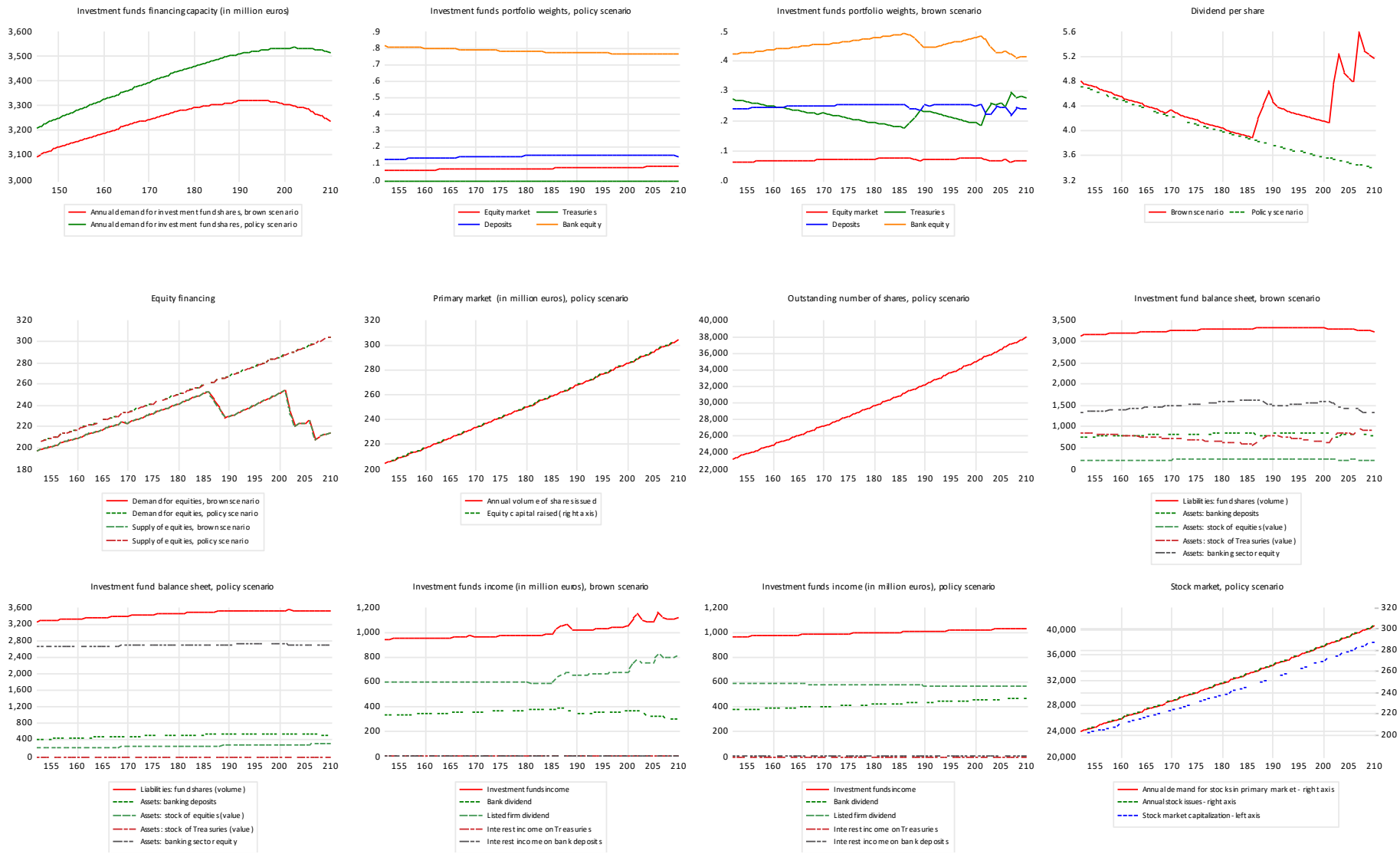


Figure A6 Ecosystem