A New Tool for Economic Policy: Central Bank Digital Currencies*

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Abstract: *Helicopter money has long been a thought experiment, impossible to implement in the real world. Today, digital technologies make it a realistic option for central banks. We study the effectiveness of helicopter money through the issuance of central bank digital currencies (CBDC) by means of a stock-flow consistent model of a growing open economy. We compare the effectiveness of this tool with that of traditional fiscal and monetary policies. We find that a CBDC can have a durable impact on GDP and crucially, it allows for the activation of a new transmission channel, which depends on the sensitivity of investment and of the interest rate to firms' leverage. But it might reduce the demand for banks' deposits, and even more crucially for loans, thus creating challenges for financial stability.*

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JEL codes: E5, G0, E12.

1 – Motivation

Technological progress in the field of digital technologies, and specifically the development of blockchain, have finally made helicopter money a real policy option for central banks and not anymore a mere thought experiment. As Buetzer (2022) puts it, "Outright Monetary Transfers" would now be feasible, in the sense of a direct transfer of resources from the central bank to firms and households. Such a policy would be engendered in the issuance of Central Bank Digital Currencies (CBDCs), namely "a digital form of Central Bank money that is widely available to the general public" (Federal Reserve, 2022a). In this work we reflect on the implications of such a new tool of monetary (or possibly hybrid fiscal) policy, and use a stock-flow consistent (SFC) model to assess its cons and pros vis-à-vis more traditional tools of fiscal or monetary stimulus.
The attribute "digital" can sometimes cause misunderstandings; indeed, that a CBDC must necessarily be a digital asset is a technical requirement – it's what make it finally possible to implement a helicopter money on large scale (Shah et al., 2020) – but it not an economic requirement and will not further be discussed here. Households, firms, and financial intermediaries already hold currency primarily in a digital form: for example, bank deposits are typically a multiple of physical cash. The difference between a CBDC and electronic currency commonly used (e.g. credit cards) is

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that a CBDC would be a direct liability of the Central Bank toward households and businesses, without the intermediation of banks or financial corporations (simplifying, one could say that households or firms begin holding reserves with the central bank).
This tool has been increasingly discussed by commentators and Central Banks especially in light of fast innovation in the private financial sector (fintech), and it has often been presented as a defensive move against market movements or experimentation from other Central Banks (Auer and Bohme, 2020; Bank of Canada et al., 2020; BIS, 2020; Kosse and Mattei, 2022; Federal Reserve, 2022a; Soderberg et al., 2022). By contrast, we consider here the possible positive contribution of CBDCs, as a way of enlarging and differentiating Central Banks' toolkit (Meaning et al., 2018; Bordo and Levin, 2017; Chen and Siklos, 2022; De Bonis and Ferrero, 2022; Federal Reserve, 2022a).
In this context, we compare the effectiveness of traditional fiscal stimulus (with monetary financing), and of so-called unconventional monetary policy, with the introduction of a CBDC, using an SFC model developed after that presented by Sawyer and Passarella (2021) on this journal. We focus on the possible introduction of a CBDC in developed economies, and leave the analysis on the possible effects of CBDCs in developing economies to future research.[1]
A prime advantage of CBDCs emerges from our analysis: their activation of a new and different transmission channel not available with the other currently available policy tools, which crucially depends not only on households' propensity to consume out of wealth, but also on the sensibility of private investment and of bank loans to firms' financial leverage.
Extant literature has highlighted a possibly crucial risk of CBDCs: that they might reduce the demand for banks' *deposits*, thus posing challenges for financial stability in so far as deposits constitute a reliable source of funding at relatively low cost for banks (Meaning et al., 2018; Bordo and Levin, 2017; Keister and Monnet, 2020; Kim and Kwon, 2022; Federal Reserve, 2022a). Our analysis shows that a reduction of the demand for banks' *loans* might be an even more serious issue, due to its negative impact on bank profitability. This both vindicates the cautious approach of most Western central banks, and calls for more research on the specific design of this policy tool.
The paper develops as follows: section 2 qualifies what precisely we mean by helicopter money, and why this term is sometimes used improperly; section 3 contextualises the CBDC in the world of cryptocurrencies and provides a short review of the literature on this topic; section 4 describes the baseline model and explains the different treatments we tested. The fifth section reports our main results, and section 6 draws some conclusions.

2 – Monetization and helicopter money

Governments have been increasingly involved in the direct or indirect monetary financing of fiscal deficits, especially when considering the fiscal efforts to tackle the pandemic-induced crisis (Romer, 2021). At the same time, Central Banks and economists are increasingly focused on how to deleverage and exit from the so-called unconventional policies they have implemented for more than a decade (e.g. Bailey et al., 2020; Federal Reserve, 2022b). Even before the recent move towards more restrictive monetary stances (which are ostensibly caused by inflation spikes), mainstream economists were already questioning the effectiveness of persistent "unconventional" monetary stimulus and widely recognized some of its drawbacks, such as the negative impact on income inequality (most recently and in connection to CBDCs, see Buetzer, 2022; for a review see, Kappes, 2021). Post-Keynesian economists have argued that fiscal policy is a more effective policy tool than monetary policy (e.g. Rochon and Setterfield, 2007; Tcherneva, 2008; Lavoie 2014), and several authors highlighted that, already before Covid hit, advanced economies were already mired in stagnation (e.g. Di Bucchianico, 2020; Fàtas and Summers, 2017; IMF, 2020).

[1] According for example to Arauz (2021), a domestic CBDC could help increase the potential of money creation in a developing economy, but foreign CBDCs could contribute to the movement offshore of domestic payment systems, and even risk facilitating capital flight.

Among the policies proposed by mainstream economists following the Great Financial Crisis and the European sovereign debt crisis, there was Milton Friedman's old proposal of monetization, known as "helicopter money" (e.g. Gali, 2020; Grenville, 2013; Reichlin et al., 2019; Turner, 2015). According to Friedman (1948), the most effective way to stimulate aggregate demand in times of crisis is to print money and channel it as a lump-sum payment to households. The rationale for this proposal lays on the fact that traditional Quantitative Easing (QE, the net acquisition of financial assets, purchased by issuing new money) does not generate direct benefits for lower income households but only general equilibrium effects, while helicopter money could be able to generate an immediate increase in households' wealth.

However, the implementation of this proposal has been commonly thought of as a fiscal expansion financed by an irredeemable loan from the Central Bank to the government. This way, despite the fact that it permanently expands the Central Bank's balance sheet, helicopter money is more akin to fiscal policy (Fullwiler, 2013).

In contrast, with a CBDC the central bank could issue new money and credit it directly on the bank accounts (with the central bank itself, or some intermediaries) of households and firms. Whereas this was not realistically possible until modern computational capabilities evolved sufficiently (as well as the standards of security and privacy of the associated software), such measure is not too different from the idea that one day a helicopter flies over a certain community and drops bills from the sky.

The introduction of a CBDC among the instruments of monetary policy could make it possible to target helicopter money operations to specific population groups, strengthening in this way the efficiency of monetary policy. During and after the Covid-19 pandemic, a number of proposals emerged in this direction (e.g. Reis and Tenreyro, 2022). However, especially if the issuance of a CBDC is targeted to a specific sector of the economy, or even to a specific class of economic units within a sector, one could ask if this measure too does not, in fact, constitute a tool of fiscal rather than monetary policy.

As a matter of fact, the boundary between monetary and fiscal policy has been blurred for a few decades now (if it has not always been). In section 4 we will investigate the effects of different economic policies that tend to be called "fiscal monetisation". The term indicates different procedures that involve an expansion of the Central Bank's balance sheet (be it permanent or temporary), combined with an increase in public deficit (Ryan-Collins and Van Lerven, 2018; Turner, 2015).[2]

However, the term monetisation is often used improperly, and in order to delineate a perimeter of our research it seems convenient to distinguish four kinds of policies: (i) an increase in deficit that leads to an increase in public debt only; (ii) an increase in the Central Bank balance sheet due to the acquisition of public debt on secondary markets; (iii) an increase in public deficit accompanied by a Central Bank purchase of public debt securities on primary or secondary markets; and (iv) deficit financing through funding from the Central Bank. In the first case there is no deficit monetization because the Central Bank's balance sheet remains unchanged; the government finances its deficit by issuing debt on the primary market. The second case represents a simple open market operation in which a monetary but not a fiscal expansion is determined. Therefore, this procedure too does not constitute monetisation. In the third case there is fiscal monetisation even if it could be enacted with a temporary monetary expansion (that the Central Bank could offset at any time by selling securities). On the contrary, when the financing of the public deficit takes place against an irredeemable debt granted by the Central Bank to the government, the Central Bank registers a permanent increase in the balance sheet.

A first consideration to be made is that these policies, besides the correct use of the term, may have different impacts on the economy. According to mainstream economists, all four options described above imply an increase in aggregate demand (though with possibly negative side effects, as mentioned in section 1). For Keynesian economists the effects of the second option (QE) are more uncertain, given the inelasticity of investment to the interest rate (Rochon, 2016), even though Keynes himself argued in the *Treatise on Money* (1930) that a policy of increasing the Central Bank balance

[2] See Ryan-Collins and Van Lerven (2018) for an in-depth analysis.

sheet through significant open market operations would reduce short- and long-term interest rates and increase security prices. This would increase the aggregate demand through a wealth effect. As mentioned, in the next section we will use a typical SFC model, encompassing the endogeneity of money as a main hypothesis, coupled with the central bank's targeting of a specific interest rate. Therefore, as will be seen, even traditional fiscal policy might imply an "automatic" change in the size of the central bank's balance sheet, aimed at preventing changes in the relevant interest rate(s). In that sense, all the scenarios we will consider exhibit some change in money supply – more or less targeted to some sectors of the economy. Our focus will be on assessing their potential impact on GDP.

A second consideration, however, that we leave for future research, is what is the democratic legitimacy of the central bank's targeting of support measures to some sectors or actors and not others, or what is the legal basis for its involvement in decision-making at least partly related to fiscal policy. We do not intend to downplay the relevance of these concerns (on which see e.g. the recent Rochon and Vallet, 2022). However, a thorough discussion of these issues would extend well beyond the scope of this paper, and would need to take into account the various constitutional and institutional environments in which central banks operate.

3 – The burgeoning literature on CBDCs

3.1 – Private and public digital currencies

In the aftermath of the Great Financial Crisis (GFC), due to growing scepticism towards the global financial and monetary system as well as technological innovations, a multitude of decentralised financial and monetary experiments flourished. The most popular of these is undoubtedly Bitcoin. The Bitcoin system, which inspired many others that followed, is able to record transactions in a decentralised, fast and transparent way. Bitcoin's challenge also relates to monetary policy as it is a currency whose growth rate is fixed (Amato and Fantacci, 2020). For this feature, Bitcoin is commonly associated with Hayekian monetary theory, though this is not accurate from a history of thought perspective (White, 1999).

Despite these technical advantages, Bitcoin has failed to take hold as a means of payment and unit of account, mainly due to its high volatility, which makes it infeasible for daily transactions by firms and households. Looking retrospectively at its price dynamics, it emerges that Bitcoin should be considered a highly risky financial asset, prone to bubbles (Sornette, 2022).

"Stablecoins" were developed to tackle these issues. As the name suggests, the goal of stablecoins is to create virtual money whose value should be stable with respect to a benchmark. This is usually achieved by pegging their price to an underlying asset or a basket of assets. These assets are mainly currencies issued by Central Banks of economically sound countries, though stablecoins pegged to baskets of securities or market indices are not uncommon (G7 Working Group on Stablecoins, 2019). On the one hand, the stability of these instruments can be ensured by fiat currency issued by safe Central Banks: in this sense stablecoins cannot claim to replace the international monetary system; on the other hand, they constitute financial instruments similar to ETFs (Exchange Traded Funds) which can lead to financial stability concerns (G7 Working Group on Stablecoins, 2019). That is why it does not seem reasonable to think of stablecoins as substitutes for traditional currencies (Carstens et al., 2021).

While private digital "currencies" (or financial assets by that name) tend to attract negative assessment in the literature, a number of authors note that introducing a (public) CBDC could lead to systemic efficiency improvements. These can be summarised on the basis of four recent documents by prime monetary institutions: the BIS (Bank of Canada et al., 2020), ECB (2020), Federal Reserve (2022a) and the IMF (Soderberg et al., 2022). First, CBDCs can be viewed as digital cash capable of replacing physical cash. This would simultaneously ensure for users the safety of having the Central

Bank money and the convenience of a bank deposit (e.g. Andolfatto, 2021; Meaning et al., 2018; Cesaratto and Febrero, 2022). Second, a CBDC reduces transaction costs (e.g. Cecchetti and Schoenholt, 2021). Third, many people who currently do not have bank deposits could access the financial system (e.g. Cecchetti and Schoenholtz, 2021). This process of democratisation of finance, in the sense of greater financial inclusion, could be a necessary condition for the implementation of unconventional monetary policies such as helicopter money (e.g. Reis and Tenreyro, 2022). Fourth, a CBDC can make it possible to track payments, facilitating in this way the containment of tax evasion and criminal activities (e.g. Meaning et al., 2018; Bank of Canada et al., 2020).

Extant literature is mainly composed of theoretical contributions since CBDCs have not been implemented at scale in almost any advanced economy. A notable exception is China, which has recently introduced the e-Yuan (or e-CNY) after a long period of experimentation that started in 2014. Some economists argue that one of the main goals of the People's Bank of China's (PBoC's) issuance of a CBDC is to expand the use of the e-CNY in the international payments system in order to erode the hegemony of the dollar as an international currency (e.g. Fantacci and Gobbi, 2021; Fantacci et al., 2022). Others do not consider this goal so relevant. In particular, in addition to the potential increase in financial inclusion and in preventing the illegal use of money, Auer et al (2020) and Allen et al. (2022) argue that the main purpose of issuing a CBDC is to tackle the spread of private cryptocurrencies.

Further pilot projects and advanced studies are currently being undertaken by the Eastern Caribbean Central Bank, the Sveriges Riksbank, and the Banco Central de Uruguay; while a central bank that has already implemented a CBDC is the Central Bank of the Bahamas[3] (Soderberg et al., 2022).

One of the main topics of discussion around CBDCs is their detailed design. Existing technology (blockchain and instant payment services) allows many degrees of freedom to policymakers, and the design of a CBDC depends primarily on the policy objectives to be achieved (Shah et al., 2020). Several aspects have so far emerged in the literature (for a review, we refer the reader to Chen and Siklos, 2022). The first concerns the type of CBDC recipient. There are two possibilities: a retail CBDC, or a wholesale CBDC. The former is a currency issued directly to households and businesses, an instrument that would allow the Central Bank to directly reach economic units currently excluded from the financial system. In contrast, a wholesale CBDC would involve financial institutions that already carry reserve deposits with a Central Bank (Boar and Wehrli, 2021). This instrument presents fewer technical difficulties and would considerably limit the process of banking disintermediation that would be generated by a retail CBDC (Bindseil, 2020). In this work we focus on the introduction of a retail CBDC, for its greater potential for innovation and to more clearly highlight the possible risks associated with it.

Another important aspect of design regards the possibility to issue an interest-bearing CBDC. On the one hand, such a tool would provide an attractive safe store of value and a safe asset for the financial system. Indeed, interest-bearing CBDCs compete with the other risk-free assets already used in the implementation of monetary policy (Bordo and Levin, 2017). On the other hand, a non-interest-bearing CBDC is a cash substitute (Panetta, 2021a).

In this contribution we analyse the possible effects of a non-interest bearing CBDC in a developed economy. We choose this option because the vast majority of projects currently under consideration by central banks are oriented in this direction (e.g. Allen 2022; Soderberg et al., 2022).

Some proponents (e.g. Panetta, 2021b) argue that, as means of payment, the CBDC is a substitute for cash and not for other financial assets. However, in so far as a deposit with the central bank has no specific time limit it is also likely to be perceived and used as a store of value; and being issued and expressed by the same entity that sets and issues the unit of account in the economy, a CBDC cannot suffer capital losses in nominal terms. Therefore, it is difficult to argue that a CBDC does not imply the Central Bank entering at least partly in the business of commercial banks. For this reason, most central banks are threading cautiously, and for example the ECB is considering a limit of 3,000€ on each individual holding of digital euros. In section 4 we will show that if agents who are credited a

[3] We do not dwell on the case given the size of the number of economic entities using a CBDC. For an overview see Soderberg et al. (2022)

certain amount of CBDC use these new resources to reduce their exposure toward commercial banks, a CBDC is not only a substitute for bank deposits, but worryingly for bank loans too.

3.2 – Studies on the economic impact of CBDCs

There is growing interest in the possible impacts of CBDCs on the economic and financial system. But with the notable exceptions of Kregel (2019) and Cesaratto and Febrero (2022), these issues have mostly been analysed by mainstream economists.[4] We focus here on the possible positive impact on GDP, as well as the possible risk for financial stability, and the interaction between the two.

Barrdear and Kumhof (2016) use a New Keynesian DSGE model to analyse the effects of a CBDC on macroeconomic variables at different phases of the business cycle. They find that a CBDC has a positive impact on GDP in the long run, and this effect is mainly due to the reduction in the interest rate. A controversial issue is the capacity of controlling monetary aggregates once a CBDC is introduced. Chen and Siklos (2022) use McCallum's monetarist approach in which the conduct of monetary policy is linked to the control of some monetary aggregates. They estimate that the introduction of a CBDC would have not been inflationary in the period from the 1970s to the 1990s.

Keister and Sanches (2021) indicate that a trade-off emerges from the introduction of an interest-bearing CBDC. On the one hand, a CBDC reduces the opportunity cost of holding money for households, and increases their demand for it. On the other hand, the increase in the cost of funding for banks translates into an increase in the cost of credit, which reduces the level of aggregate investment. Considering an oligopolistic bank deposit market, Chiu et al (2019) show that higher deposit rates can increase lending by increasing the demand for deposits. The authors show that the introduction of a CBDC provides a lower bound on deposit rates, limiting banks' monopoly profits in the deposit market.

Kim and Kwon (2022) emphasise the importance of bank's reserves in examining the effects of introducing a CBDC. The authors show that for a wholesale CBDC an increase in the amount of the CBDC that does not require banks to hold reserves could even strengthen financial stability and lower interest rates.

On the same issue, Keister and Monnet (2020) point out that in times of financial stress, CBDCs are preferred by economic agents over bank deposits, for example because of their lower (or absent) counterparty risk. Therefore, the authors emphasise the macroprudential importance of observing the aggregates of deposits and CBDCs in order to monitor the bank run risk perceived by economic agents.

4 – Helicopter money, quantitative easing, and fiscal transfers in a stock-flow consistent model

The SFC approach is especially suitable for the assessment of complex economic systems. In particular, it ensures the consistent integration of the stocks and flows of all the sectors in the modelled economy through the compliance with four main accounting principles: flow consistency, stock consistency, stock-flow consistency, and quadruple-entry accounting (Godley and Lavoie, 2012; for a survey on the SFC methodology, see Nikiforos and Zezza, 2017). Among the advantages of the SFC approach for our aims is the importance given to money, credit, the financial system and banks; but the complexity of these models is a shortcoming that in some cases could complicate the direct interpretation of some mechanisms (Passarella, 2012).[5]

[4] For a comprehensive overview of the literature see Carapella and Flemming (2021), Bank of Canada et al. (2021), or Chen and Siklos (2022).

[5] Previous attempts at integrating new financial assets/liabilities as an innovative tool of economic policy into SFC models have been proposed for example by Dowicquet et al. (2018), who study Eurobonds as a financial instrument in order to

Within the SFC literature we selected the recent Sawyer and Passarella (2021) model as the baseline structure in which to introduce a CBDC. This model was designed with the explicit aim to provide a comprehensive comparison of fiscal and monetary policies, including so-called "unconventional" measures such as Quantitative Easing (QE). It especially suits our aims because, differently from other contributions in this literature, it has not been designed to mimic the dynamics of any specific country, but rather to approximate those of an advanced capitalist economy. In our simulations, we too calibrate the model to roughly reproduce conditions of "secular stagnation".

In order to preserve the comparability of our results, we have modified the original structure of the model as little as possible (except for the introduction of the CBDC). Table 1 represents the nominal balance sheet of each sector, while Table 2 shows the transaction flows.[6] Sawyer and Passarella's (2021) model consists of seven sectors: lower-class households, upper-class households, production firms, commercial banks, central bank, government, and foreign sector. lower-class households use their income to consume and save. Their consumption depends on their disposable income, their stock of wealth, the amount of cash they hold, cheque deposits, as well as the previous quarter's consumption; we include the CBDC among the determinants of consumption. The lower-class households might demand loans to commercial banks in order to bridge the gap between their desired consumption and their disposable income. Upper-class households receive the remaining part of the aggregate household income, and they hold a range of financial assets. In addition to the options available to lower-class households, they can allocate their wealth in an interest-bearing savings deposit, government bills, and firms' shares. Their portfolio choices are based on Tobinesque principles (see online Appendix 2.3 for the full model).

Production firms (Appendix 2.1) are owned by the upper-class households and the members of both types of households are employed in this sector. Workers and managers earn different wages, while firms' investments depend on an endogenously determined target level of capital (which among other things depends on their financial leverage) and are financed by retained earnings and bank loans. Regarding the banking sector (Appendix 2.4), the model assumes zero production costs; the banking sector is subject to prudential requirements, and it distributes all profits to the shareholders (upper-class households, see Appendix 2.4).

The government sector provides transfers to the private sector, and collects taxes from both classes of households. It finances any deficit issuing public debt (Appendix 2.5). The model assumes that all the profit generated by the Central Bank is entirely transferred to the government, so that in practice in our parametrization the central bank's net worth is always zero.

Finally, the Central Bank fixes the policy rate. In this way, the money supply is endogenously determined by the economic system. The Central Bank acts as the lender of last resort: it buys all the unsold government bonds and it receives all reserves that the commercial banks may wish to hold on top of the required reserves, and/or it provides any loans (advances) that the commercial banks might demand (Appendix 2.7).

reduce territorial inequality within a currency union; and Dafermos et al. (2017), who study the use of financial assets as a means to reach ecological/environmental goals.

[6] With respect to the original model, in addition to the inclusion of assets and liabilities related to the CBDC, in table 1 we also modified the value of the central bank's net worth, to allow it to be different from zero in principle. This would happen if, for example, a CBDC was issued as a grant instead of a loan, with a net negative impact on the central bank's balance sheet. This case is not considered in this paper because it would not qualitatively differ from the case of CBDC designed as an open-ended loan, considered in the next section.

Table 1: Balance sheet matrix

	Lower-class households	Upper-class Households	Production firms	Commercial banks	Central bank	Government	Foreign sector	Σ
Cash	$+h_w$	$+h_r$			$-h_s$			**0**
Account deposits	$+m1_w$	$+m1_r$		$-m1_s$				**0**
Savings deposits		$+m2_h$		$-m2_s$				**0**
Loans	$-l_h$		$-l_f$	$+l_s$				**0**
CBDC	$+\boldsymbol{CBDC_w}$	$+\boldsymbol{CBDC_r}$	$+\boldsymbol{CBDC_f}$		$-\boldsymbol{CBDC_s}$			**0**
CBDC loans	$-\boldsymbol{l_{CBDCw}}$	$-\boldsymbol{l_{CBDCr}}$	$-\boldsymbol{l_{CBDCf}}$		$+\boldsymbol{l_{CBDCs}}$			**0**
Required reserves				$+hb_d$	$-hb_s$			**0**
Discretionary reserves				$+hb_d^*$	$-hb_s^*$			**0**
Central bank advances				$-a_d$	$+a_s$			**0**
Capital stock			$+k$					$+k$
Shares issued		$+e_h$	$-e_s$					**0**
Government securities		$+b_h$		$+b_b$	$+b_{cb}$	$-b_s$		**0**
Official reserves (net)					$+h_f$		$-h_f$	**0**
Balance (net worth)	$-v_{wn}$	$-v_r$	$-v_f$	$-v_b$	$-v_{cb}$	v_g	v_{fs}	$-k$
Σ	0	0	0	0	0	0	0	0

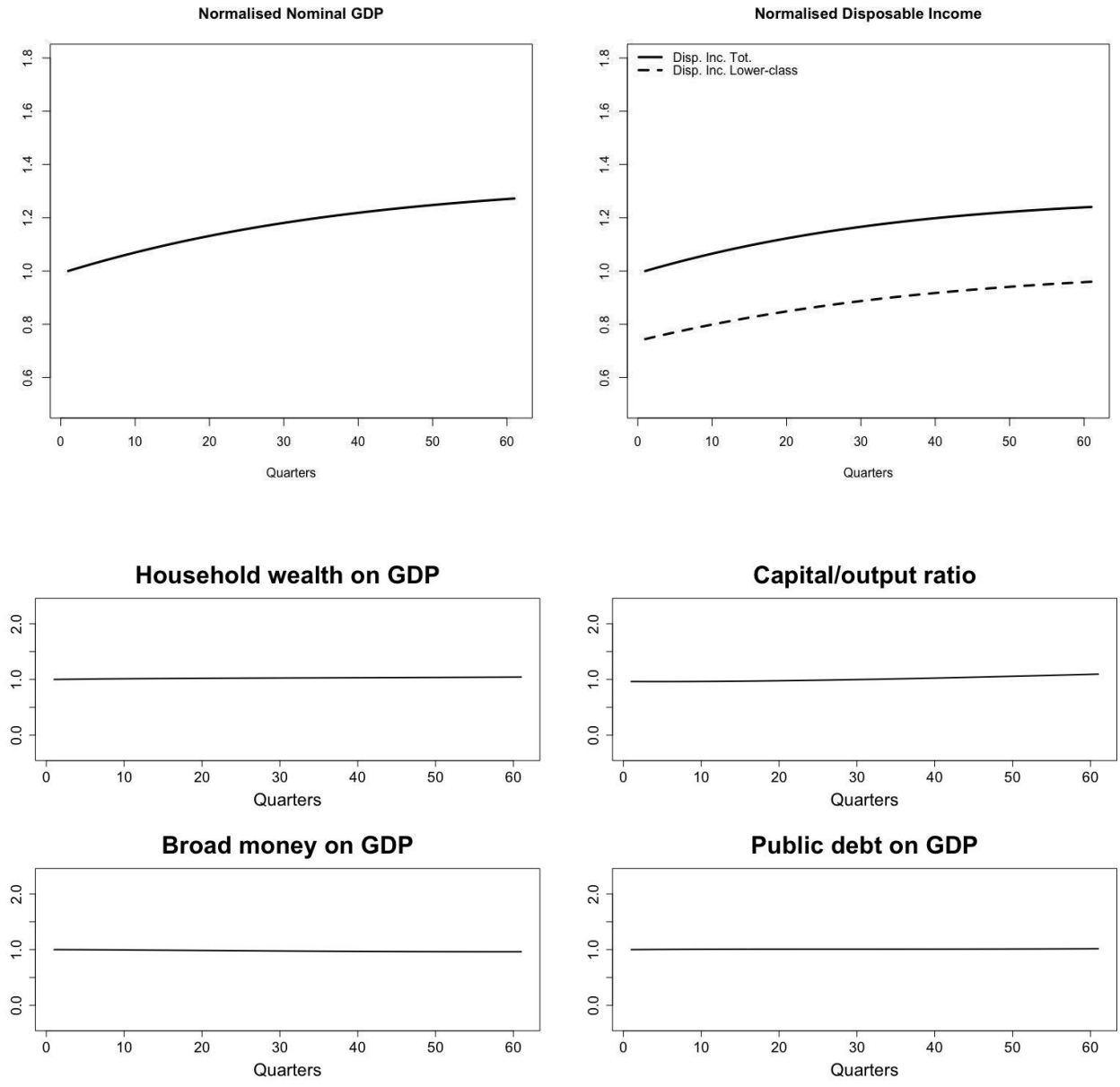
Table 2: Transaction-flows matrix

	Lower-class households	Upper-class households	Production firms		Commercial banks	Central bank	Government	Foreign sector	Σ
			Current	Capital					
Consumption	$-c_w$	$-c_r$	$+c$						**0**
Investment			$+id$	$-id$					**0**
Government spending			$+gov$				$-gov$		**0**
Export			$+x$					$-x$	**0**
Import			$-im$					$+im$	**0**
Memo: national income			$[y]$						
Taxes on income and wealth	$-tax_w$	$-tax_r$					$+tax$		**0**
Fiscal transfers	$+tr_w$	$+tr_w$					$-tr$		**0**
Wage bill	$+(1-\Omega_r)\cdot wb$	$+\Omega_r \cdot wb$	$-wb_f$				$-wb_g$		**0**
Interest on loans	$-rl_{-1}\cdot lh_{-1}$		$-rl_{-1}\cdot lf_{-1}$		$+rl_{-1}\cdot ls_{-1}$				**0**
Repayments on loans	$-rep\cdot lh_{-1}$				$+rep\cdot lhs_{-1}$				**0**
Interests on savings deposits		$+rm_{-1}\cdot m2h_{-1}$			$-rm_{-1}$ $\cdot m2s_{-1}$				**0**
Return on government securities		$+rb_{-1}\cdot bh_{-1}$			$+rb_{-1}\cdot bb_{-1}$	$+rb_{-1}\cdot bcb_{-1}$	$-rb_{-1}\cdot bs_{-1}$		**0**
Seigniorage income						$-f_{cb}$	$+f_{cb}$		**0**
Entrepreneurial profit		$+fd_f$	$-f_f$	$+fu_f$					**0**
Amortisation funds			$-a_f$	$+a_f$					**0**
Bank profit		$+f_b$			$-f_b$				**0**
***Change* in cash**	$-\Delta h_w$	$-\Delta h_r$				$+\Delta h_s$			**0**
***Change* in CBDC**	$-\boldsymbol{\Delta CBDC_w}$	$-\boldsymbol{\Delta CBDC_r}$		$-\boldsymbol{\Delta CBDC_f}$	$+\boldsymbol{\Delta CBDC_f}$	$+\boldsymbol{\Delta CBDC}$			**0**
***Change* in CBDC loans**	$+\boldsymbol{\Delta l_{CBDCw}}$	$+\boldsymbol{\Delta l_{CBDCr}}$		$+\boldsymbol{\Delta l_{CBDCf}}$		$-\boldsymbol{\Delta l_{CBDC}}$			**0**
***Change* in loans**	$+\Delta l_h$			$+\Delta l_f$	$-\Delta l_s$				**0**
***Change* in account deposits**	$-\Delta m1_w$	$-\Delta m1_r$			$+\Delta m1_s$				**0**
***Change* in saving deposits**		$-\Delta m2h$			$+\Delta m2_s$				**0**
***Change* in shares**		$-\Delta eh\cdot pe$		$+\Delta esr\cdot pe$					**0**
***Change* in government securities**		$-\Delta bh$			$-\Delta bb$	$-\Delta bcb$	$+\Delta bs$		**0**
***Change* in Required reserves**					$-\Delta hbd$	$+\Delta hbd$			**0**
***Change* in Discretionary reserves**					$-\Delta hbd^*$	$+\Delta hbd^*$			**0**
***Change* in Central bank advances**					$+\Delta ad$	$-\Delta ad$			**0**
***Change* in official reserves (net)**						$-\Delta hf$		$+\Delta hf$	**0**
Σ	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

4.1 - Baseline scenario

Similarly to Passarella and Sawyer (2021), we do not calibrate our model to a specific economy because, in this preliminary work, we are interested in showing from a theoretical point of view some of the possible effects produced by a CBDC on a complex economic system approximating the conditions of a generic advanced economy. The model's parameters and initial values are retrieved from the literature on SFC models or from time series on the U.S. economy. For a full list of the single parameters, see the online Appendix 3. We interpret a period in the model as a quarter of a year.

Figure 1 - The baseline scenario: an economy in secular stagnation



Notes: all values have been normalised to equal one in the first period shown ($t = 0$).

In the baseline scenario, generated by our parametrization without any shocks, the model represents a growing economy, albeit at a very slow pace, consistent with the secular stagnation hypothesis. As shown in figure 1, nominal GDP grows by about 13% in 60 quarters (i.e. 15 years). Households' disposable income has a similar increasing trend, and the aggregate value of the disposable income of the lower-class households is always higher than for upper class-households. This is because we assume that the former constitute 75% of the population. As shown in the figure, our baseline economy is in a (low) steady-growth path, with stable values of the capital, wealth, public debt, and broad money to GDP ratios.

4.2 - Treatment analysis

On this baseline, we simulate four main treatments. The time horizon of our simulations is 130 periods, and each period can be interpreted as a quarter. The system is always hit by a shock at the 70th period (that we refer to as period 1 throughout and in all figures, as dating in our terminology starts from the shock). Table 3 summarises the four treatments tested.
In treatment 1, "fiscal transfers to households", the government deliberates new social transfers to households for a total value of 5% of the GDP of the previous period; the shock lasts one period. The amount of transfers is divided between the two classes of households in proportion to their share of aggregate household disposable income (approximately 75% for lower-class households, and 25% for upper-class households).

Table 3. Description of the treatments

Scenario	Treatment	Target sector	Shock type	Transmission channel
1	Fiscal transfers to households	All households	The government increases social transfers to households by 5% of the previous period's GDP value	Marginal propensity to consume out of income (MPCY)
2	CBDC to households	All households	Issuance of CBDC credited to households equal to 5% of the previous period's GDP value	Marginal propensity to consume out of wealth (MPCW)
3	CBDC to firms	Firms	Issuance of CBDC credited to firms equal to 5% of the previous period's GDP	Sensitivity of investments, and of the interest rate to firms' leverage
4	Quantitative Easing	Upper-class households	The Central Bank purchases government bonds held by households for a value equal to the 5% of the previous period's GDP	MPCW

In the "CBDC to households" and in the "CBDC to firms" cases (Treatments 2 and 3) we assume that the Central Bank engages in helicopter money operations for 5% of the previous period's GDP. And under the "Quantitative Easing" (Treatment 4), the Central Bank decides to increase its holdings of government securities by a value equal to 5% of the pre-shock's GDP. In order to ensure the comparability of their effectiveness, the hypothesized shocks have the same size for all treatments. This choice follows from our primarily theoretical aims, but evidently constraints the realism of the results, which should be interpreted allowing for the fact that 5% of GDP is large shock for fiscal

policy, and probably a small one for QE. Concerning helicopter money, as already mentioned some central banks (e.g. the ECB) are currently considering an absolute ceiling to each individual's holding of digital currency, so that the aggregate shock might ultimately prove smaller than 5% of GDP.

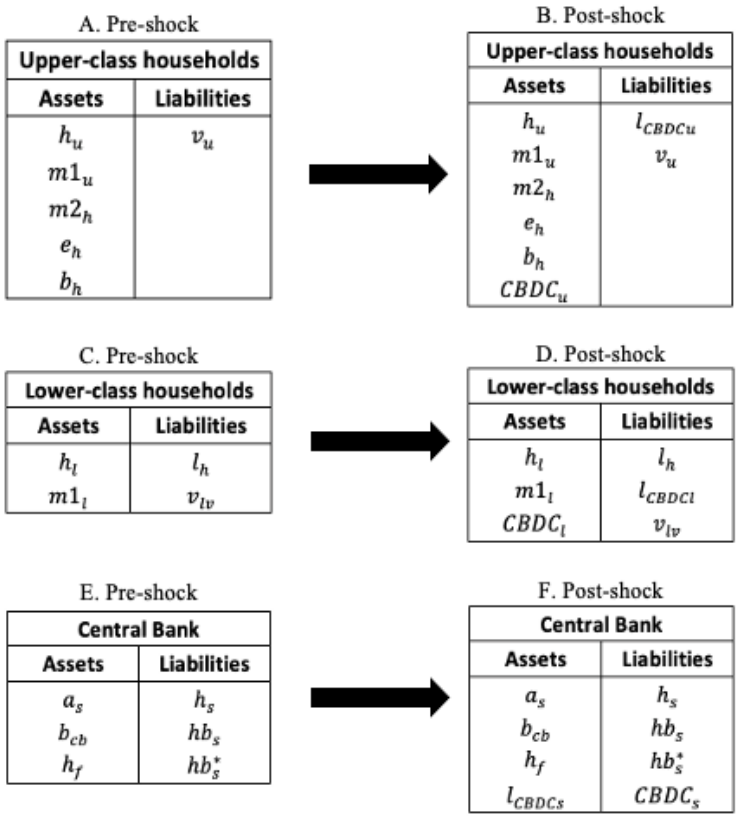
In terms of design, treatment 2 is a non-interest-bearing retail CBDC designed as an open-ended loan. We chose this design because it is a generalization in terms of how it is represented in the various sector's consolidated balance sheets (figure 2). As an irredeemable loan, it is not qualitatively different from a grant (or an "outright monetary transfer").[7] But as a loan, in principle it would always be possible for the central bank to impose an interest rate and/or an expiration date, providing more degrees of freedom to this policy tool.

We assume that the Central Bank carries out such expansionary policy by increasing its balance sheet. The shock consists of one-off crediting of CBDC to all households (in Appendix 1, figure A6, we discuss the case of targeting one class or the crediting of the CBDC with variable shares for the two classes of households). We hypothesise that the Central Bank first sets the total value to issue to households and then it establishes the shares for lower and upper-class households. In order to implement this monetary policy, the Central Bank decides to open a current account for each household. This generates two new accounting entries: the new stock of CBDC (households' deposits), which is the CBDC as a means of payment, and the loan to the recipient households, which is its accounting counterpart. We assume that the issuance happens only once and that the loan is never due to be repaid within the horizon of our simulations, in order to consider expansionary shocks only (they are what Buetzer, 2022, calls "perpetual zero-coupon targeted long-term lending operations"). Therefore, this treatment qualifies as a case of helicopter money.

In figure 2, panels A, C, and E respectively report the balance sheets of the upper- and lower-class households and of the Central Bank before the shock, while panels B, D, and F report their balance sheets after the shock. After the shock, households experience an increase in their assets due to the Central Bank crediting the CBDC on their account. On the liability side, households register a debt of the same value of the CBDC toward the Central Bank. On the Central Bank's balance sheet, this implies that a new liability (CBDC) and a new asset (l_{CBDC}) of the same value are registered. Therefore, the total size of the Central Bank's balance sheet grows exactly by this amount. After this shock, we assume that households consider the CBDC as a substitute for their bank deposits, and indeed they use bank money for consumption or other transactions and hoard the CBDC as much as they can, because following the literature we assume that the CBDC is perceived to be safer and more convenient than bank deposits (thence the risks for the stability of the banking system).

[7] In Appendix 1.3 we show how to account for the issuance of CBDC as a grant, in the balance sheets of the central bank and of the recipient households. In this case, the second entry in the central bank's balance sheet would be a net loss (a reduction in own resources or capital), and in the households' balance sheet, it would be a capital gain. We do not further consider this case because the results are not qualitatively different from those considered here, with the additional complication that the central bank's capital might turn negative – a contentious possibility that has caused debate e.g. during the eurozone crisis.

Figure 2 – Treatment 2: balance sheets



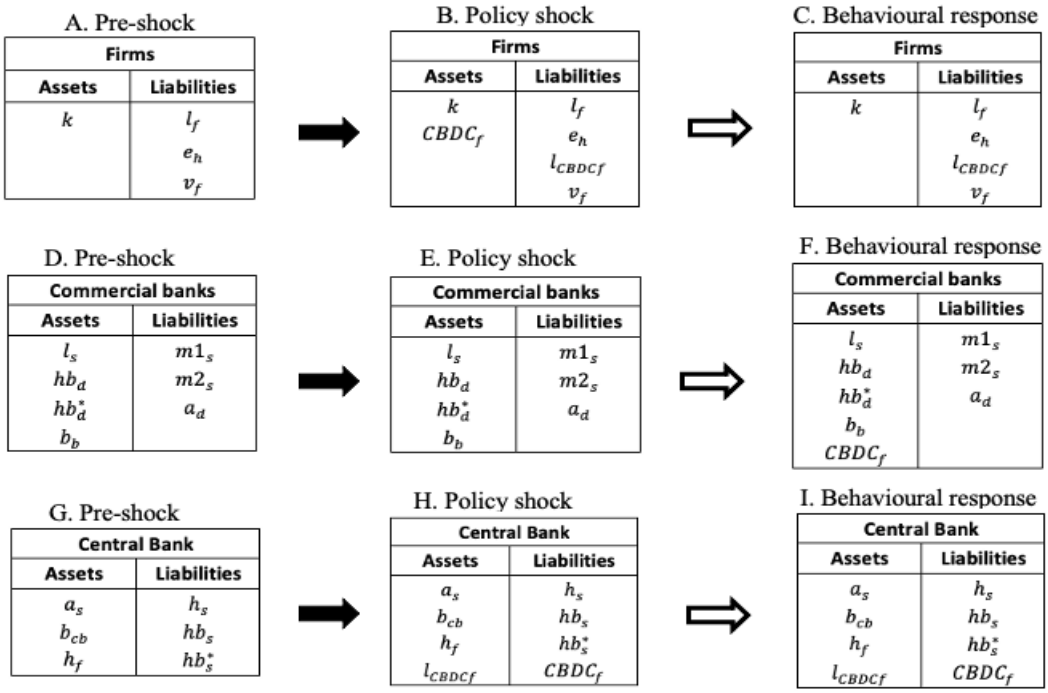
The third treatment is the "Central Bank Digital Currency targeted to firms". We consider a non-interest bearing retail CBDC, with the same design as the previous treatment. We assume that the Central Bank grants an irredeemable loan to firms, recording it on the assets side of its balance sheet. The liabilities of the Central Bank increase by the same amount, because we assume again that the central bank opens an account with each non-financial firm in the economy. The opposite happens in the balance sheet of firms.

This treatment involves three assumptions. Again, we assume that the Central Bank's loans never have to be repaid by firms during the simulation period. Understanding this, firms and their creditors (commercial banks) treat the loan as one of infinite duration or even not too differently from a form of equity, and therefore they perceive a reduction in firms' financial leverage (which in our model implies a reduction in the interest spread imposed on firms, and an increase in firms' desired level of capital). Second, we assume that firms use the CBDC to reduce their debt to banks, preferring instead the newly acquired non-interest bearing debt toward the central bank. This assumption is a choice concerning the composition of firms' liabilities and not their overall level: since firms are not liquidity constrained, they already had the desired level of liabilities before the shock. However, since the central bank charges a lower interest rate (zero, in our assumption), they prefer the central bank loan over the commercial banks' loans. And since firms do not have unused free cash flow, they use their CBDC account (an asset on their balance sheet) to repay their loans toward the commercial banks. Finally, we assume that banks consider the CBDC as a perfect substitute for their other account(s) with the central bank, i.e. traditional reserves. Therefore, when they receive the CBDC from the firms banks correspondingly decrease their demand for discretionary reserves with the central bank.

Figure 3 shows the balance sheets of the three sectors involved (firms, commercial banks and the Central Bank) at three different points in time: before the shock, immediately after the shock, and after the behavioural reaction. The division into three phases is useful to understand the intra-period dynamics between the various sectors. In particular, as soon as the CBDC is given to firms, they use

it to reduce their debts with the banking system; in turn, banks reduce their demand for (discretionary) reserves when they receive from firms a transfer in the form of CBDC. As a consequence, the central bank's balance sheet does not increase by the amount of the original shock, because of the reduction in its liabilities towards the commercial banks.

Figure 3 – Treatment 3: balance sheets

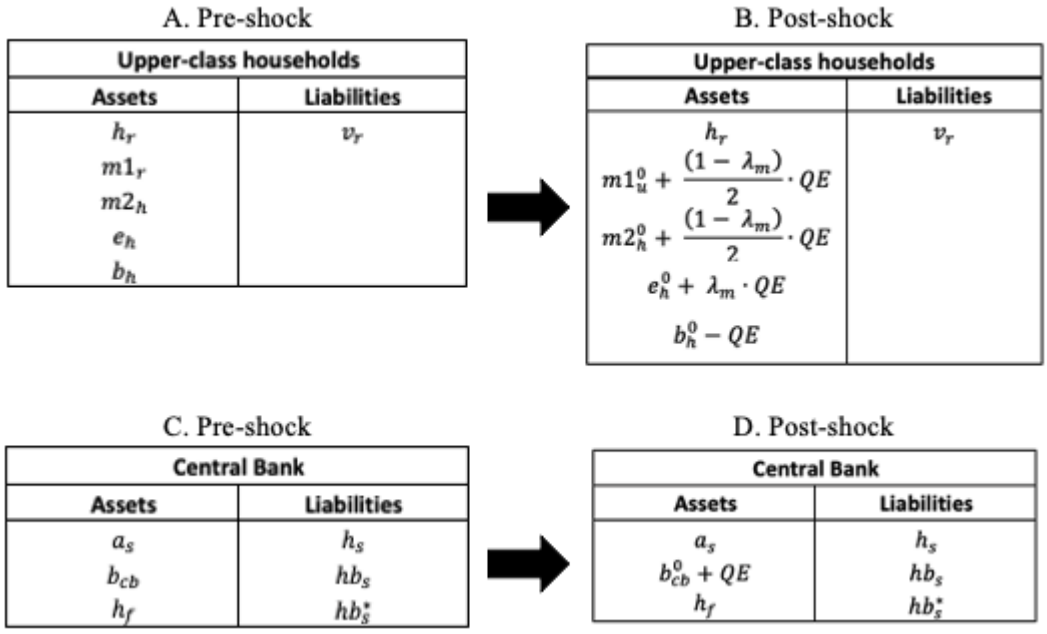


The last treatment considered here deals with "traditional" Quantitative Easing. In order to improve the comparability with the other treatments, we slightly change Sawyer and Passarella's QE scenario. In Sawyer and Passarella (2021), the Central Bank sets the amount of government securities it wishes to buy from the upper-class households. When upper-class households reduce their holdings of government debt, they increase their bank deposits by the same extent, which in turn implies an increase in the banks' required reserves too. In our treatment, instead, we assume that when upper-class households see their government bonds decrease, they revise the allocation of their portfolio by partly increasing their bank deposits, and partly increasing their holdings of firms' equities. This change to the original model (one of the very few ones) is meant to allow for more and larger transmission channels of this monetary policy to the real economy; yet, as shown in the next section, QE will emerge as the least effective treatment anyway.

As a result of upper-class households' increased demand for shares, asset inflation emerges. This both implies some capital gains for the holders of shares (upper-class households, again) and to some extent it stimulates firms' investments and their issuance of new shares. Notice that in this case the upper-class households' capital gains are unrealized profits: indeed, in this model only they hold shares, so any capital gain on this asset cannot imply a net transfer of resources from other sectors and at most it will result in a redistribution of wealth within this class. Including such asset inflation

among the capital gains, and therefore in the change in upper class households' net wealth, leads to higher consumption spending due to higher (nominal) wealth.[8]

Figure 4 – Treatment 4: balance sheets



Notes: the terms with superscript 0 (namely, $m1_u^0$, $m2_h^0$, e_h^0, b_h^0, and b_{cb}^0) denotes the respective values at the beginning of the period. They are used here in order to visually highlight the central bank's policy shock and the households' choice on how to redistribute the newly acquired money (in exchange for bonds) between alternative financial assets (namely, checking deposits, saving deposits, and stocks). The assets side of panel B ignores for simplicity the additional deposits and additional demand for firms' shares originated by the economic growth (and therefore the increase in households' incomes and wealth) during the period.

Figure 4 shows the balance sheets of the relevant sectors involved, before and after the shock (panels A, B, C, and D). Panel B shows the portfolio reallocation of upper-class households induced by the QE, while Panel D shows the asset side growth in the balance sheet of the Central Bank, by the amount of government bills bought on the secondary market.

5 - Main results

As mentioned, rather than trying to replicate the economic dynamics of a specific country, we focus on comparing the various treatments and on highlighting what non-trivial findings emerge due to general equilibrium effects (i.e., indirect feedbacks, and stock-flow adjustments). In what follows we assess the effectiveness of a certain policy by its impact on nominal and real GDP; and we compare the respective implications for public and private finance. For all four treatments, we consider a shock worth 5% of previous quarter's GDP. Table A1 in appendix 1 reports additional results in terms of

[8] The same occurs as a consequence of goods prices inflation, which in principle would have to imply a reduction in real disposable income due to a negative wealth effect (Godley and Lavoie, [2007] 2012, pp. 289-291; pp. 293-294), which is instead ignored here. Therefore, the model implies that households suffer from monetary illusion. We thank Marco Passarella for raising this point with us.

variables not considered here, which figures A1 to A8 report robustness checks under alternative assumptions.

5.1 - GDP dynamics

As shown in Figure 5, all four treatments imply a positive impact on GDP in the short term, both in nominal and in real terms. This positive effect is a direct consequence of an increase in consumption, and then a multiplier and an accelerator effect. More specifically, an increase in transfers impacts on consumption via the propensity to consume out of income (MPCY, see e.g. Carroll et al., 2017; Drescher et al., 2020), while QE and the CBDC to households have a direct effect on wealth and, consequently, on consumption via the propensity to consume out of wealth (MPCW, see e.g. Drescher et al., 2020). In the QE scenario, this phenomenon is led by asset inflation as a result of an increase in the demand for equities. In contrast, in treatment 3 (CBDC to firms), output growth is due principally to an increase in firm's investment triggered by firm's deleveraging (e.g. Myers, 1977; Roxburg et al., 2010).

Regarding the short-term impact on GDP (i.e. considering 20 quarters, or 5 years, after the shock), the two treatments that implement a CBDC perform better than both fiscal transfers and QE. In this sense, no substantial discrepancies emerge comparing the dynamics of nominal and real GDP.

Considering the long run effects (40 quarters, or 10 years, after the shock), expansionary fiscal policy stabilises real GDP at a higher level than the pre-shock value (that is, the model exhibits some long-term impacts of fiscal policy). The two scenarios based on the introduction of a CBDC exhibit even higher levels of production in both nominal and real terms. Instead, the QE's positive impact on real GDP fades away in the long run, realigning its level to that of the baseline scenario (with no shocks).[9] This behaviour highlights what Rochon (2022) calls "the general ineffectiveness of monetary policy" and arises because fewer government bills held by the private sector over time imply lower net public expenditure for interest payments (recalling that all central bank's profits are returned to the government) and therefore lower income and lower consumption of the upper-class households. Effectively, QE substitutes unrealized capital gains for realised capital incomes, with even a potentially negative impact in the long run.

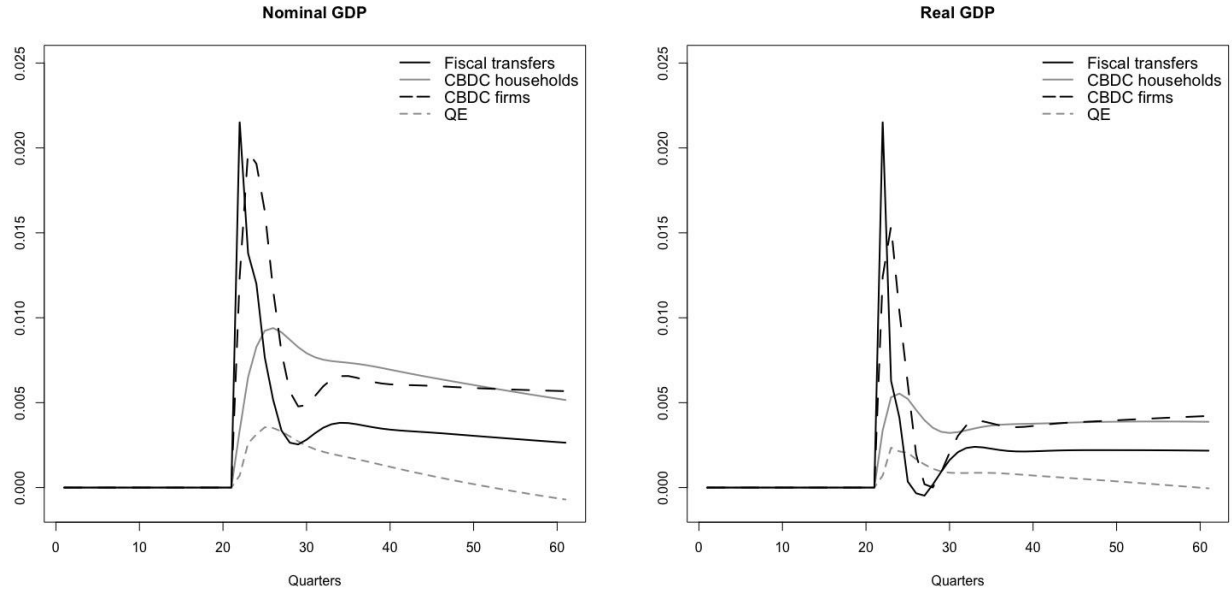
To understand why the issuance of CBDC seems to result in a larger boost to GDP, in Appendix 1 we develop a sensitivity analysis specifically aimed at understanding to what degree our results depend on the specific parametrization used here.

Evidently, the behavioural assumptions about what firms and/or households do with the newly acquired CBDC are the most relevant candidate explanation. Concerning households, our approach of assuming that families value the CBDC more than bank money (deposits) represents a conservative approach, aimed at highlighting some of the risks for financial stability discussed in the literature (see section 4.3). However, there are no strong reasons to believe a priori that households would consume a given share of the CBDC they receive. The results shown in figure 5 are based on an assumed propensity to consume the CBDC of 5%, corresponding to the assumption that households consume the whole transfer from the central bank (arguably perceived as a transitory income) within 20 years. In figure A2 in the appendix we report the simulation results assuming that households consume the CBDC in the same proportion as bank deposits (1%) as well as their propensity to consume the total wealth of upper-class (2%) and lower-class households (3%). We find that if households spend the CBDC in the same proportion as bank deposits the GDP impact of this treatment is lower than public transfers, while if they spend at least 1.5% of the CBDC, the impact is higher both in the short and in the long term. Therefore, this parameter must certainly be regarded as the crucial variable on which the real-world effectiveness of this measure hinges. In certain contexts, policymakers could try to

[9] The small difference between real and nominal dynamics can be attributed to low levels of inflation consistent with the secular stagnation hypothesis of Passarella and Sawyer's (2021) model.

affect this variable by experimenting with an interest-bearing CBDC, whose precise impact is left for future research.

Figure 5 – Nominal and real GDP



Notes: for each period, the values shown are ratios to the corresponding value in the baseline scenario minus 1.

Concerning firms, we tested what would be the GDP impact if they used at least part of the CBDC loan from the central bank to increase their investments rather than to decrease their debts towards banks. As shown in figure A1, using the same percentages of CBDC invested as we assumed households would consume in the previous exercise (1%, 2%, and 3%), the results always denote an even (slightly) greater effectiveness of this policy tool than our main result in figure 5. However, while these increased investments provide a small short-run boost to GDP, in the long term no substantive changes are visible. This is because in Passarella and Sawyer's (2021) model firms are not liquidity constrained in they can always obtain the funding for investments from banks. In the long term, banks will lend money charging a lower interest rate if firms have a lower financial leverage, so for firms deleveraging might be the best long-term strategy in this treatment (depending on a number of other parameters or emergent properties, e.g. the long-term growth stimulated by the short-run increase in investments).[10]

Symmetrically, for the fourth treatment too we test the relevance of our behavioural assumptions in driving the result of a rather low GDP impact of QE. In figure A8 we consider a range of different portfolio shares allocated by the upper-class households in equities (rather than in saving deposits) following their selling of bonds to the central bank. When the demand for equities increases, their price increases too; this produces unrealized capital gains for the upper-class households, thereby increasing their consumption (Joyce et al., 2010; Fratzscher et al., 2016). Therefore, in our analysis

[10] Given the GDP impact found for this treatment, one might suggest implementing a CBDC targeted to particularly indebted sectors (although not in the context of CBDCs, this topic has been explored in depth by the McKinsey Global Institute: Roxburg et al., 2010).

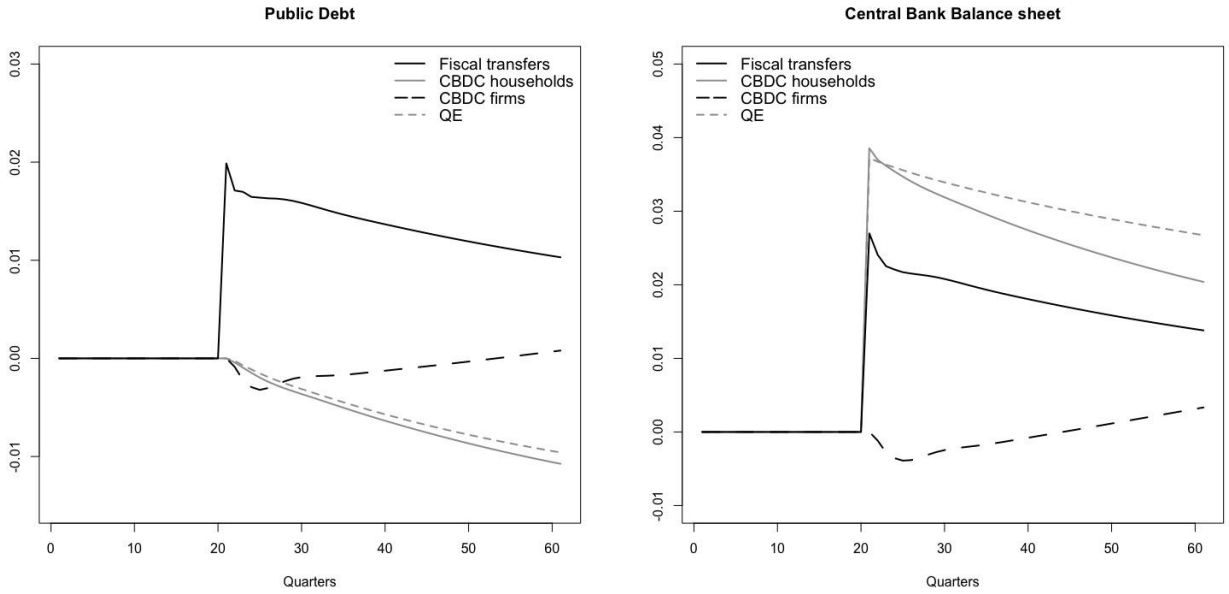
the greater the proportion of the portfolio reallocated to equities instead of saving deposits, the greater the positive impact of QE on GDP.
Next, as a robustness check we consider the possible role of the design of CBDC issuance. Specifically, we modify the shares of recipients of the CBDC - and for comparison of fiscal transfers too - in terms of the two classes of households. Considering treatment 1, we find that targeting the social transfers to lower-class households increases the GDP impact of this treatment immediately after the shock (e.g. Oh and Reis, 2012); but after that, as shown in figure A5, the GDP impact is actually slightly larger when transferring relatively more resources to upper-class households, and anyway the impact decreases over time, so that in the long run the respective shares do not matter. The greater effectiveness of transferring resources to upper class households, in this model, is due to the positive wealth effect generated by financial investments of wealthy households and their effect on aggregate demand and general equilibrium effects over time (Kuvshinov and Zimmermann, 2022; Patara et al., 2013).
Considering treatment 2, we find similar results: GDP increases more when crediting relatively more CBDC to upper-class households (figure A6). Finally, in the Appendix 1 we show the GDP impact of different assumptions on the values of other values, characterising all treatments and the baseline, which could nonetheless affect the GDP impact of one or more treatments in particular. We consider: the marginal propensities to consume out of income and wealth, for either or both classes of households; and the elasticity of firms' investments and of the interest rate on banks' loans to firms' financial leverage. In all cases, the results are trivial and do not necessitate further analysis here, except to say that they do not imply a qualitative change in the main results commented on in this section.

5.2 - Public sector finances

Concerning financial aspects related to the public sector, in figure 6 we show the trends in the four treatments of the government debt and the size of the central bank's balance sheet, with respect to the baseline scenario.
The effects of the first treatment are those traditionally produced by expansionary fiscal policies accompanied by some degree of monetization (Coenen et al., 2012; Oh and Reis, 2012; Lavoie, 2022). Specifically, we find an immediate increase in public debt that is only partially reabsorbed over time by higher tax revenues and higher seigniorage income. Such partial compensation is due, to some extent, to the model assumption that government spending increases as a function of the previous quarter's GDP. The central bank's balance sheet shows a similar trend, peaking during the shock and then declining, because the central bank is a buyer of last resort of sovereign bonds (e.g. Hawkins, 2003; Caruana, 2012).
The second treatment implies a reduction in public debt with respect to the baseline both in the short run and in the long run. Evidently, such dynamic is due to the fact that the stimulus (CBDC) is financed through an irredeemable loan from the central bank (not included within public debt), while the increase in GDP results in higher public receipts and therefore lower deficit (e.g. Turner, 2015; Tenreyro, 2022). The central bank's balance sheet rises exactly by the value of the CBDC issued, and then it constantly lowers down. Such reduction after the shock is mainly attributable to the lower stock of public debt held by the central bank, and the lower banks' reserves due to reduced household demand for deposits (see next section).
Treatment 3 results in an immediate reduction of public debt and of the size of the central bank's balance sheet, but both variables increase over time and in the long run they grow above the baseline scenario. Such - not immediately intuitive - dynamic can be explained by firms' lower demand for loans after the shock, which forces commercial banks to reallocate their assets buying more public bonds, which in turn makes it necessary for the central bank to buy fewer of them (thus with a

reduction of its balance sheet).[11] However, a greater proportion of public debt owned by the private sector implies lower seigniorage income for the government, triggering a growth in its deficit. In these respects, the deleveraging mechanism triggered by the CBDC issued to firms, as well as its effects on the banking system, differs substantially from the dynamics of firm's deleveraging normally observed in real contexts (e.g. Roxburg et al., 2010; Cuerpo et al., 2015).

Figure 6 – Public debt and the central bank's balance sheet



Notes: for each period, the values shown are ratios to the corresponding value in the baseline scenario minus 1.

Finally a short-run effect of QE, our fourth scenario, is the growth in the size of the central bank's balance sheet and a decrease in the stock of outstanding government debt with respect to the baseline (e.g. Federal Reserve, 2022b; Bailey et al., 2020; Haldane et al., 2016). The latter is caused mainly by two factors: one is the increase in government revenues due to higher central bank profits, generated by the higher stock of debt owned by the central bank (both in the short run and in the long run); and the other depends on the higher tax revenues induced by the economic expansion caused by the QE (in the short run only). A lower public deficit, however, gradually produces a reduction in total public debt, which results in a gradual reduction in the total size of the central bank's assets too. The sensitivity analysis in Appendix 1 shows the effects of treatments 1 and 2 on the public deficit and debt in the short run and in the long run. In treatment 1, the share of fiscal transfers that are targeted to either class of households is practically irrelevant in the short run; in the long run, it leads to a slight discrepancy whereby a lower stock of debt is associated with a higher share of transfers to upper-class households. This correlation is driven by the fact that the impact on GDP is more persistent when the share of transfers to upper-class households is higher, as discussed in the previous sub-section. In treatment 2 too, the different impact on deficit and debt associated with a different targeting of the CBDC is driven by the different impact on GDP: as a higher share of CBDC credited

[11] The results do not significantly change if we assume that banks demand more, or even exclusively, discretionary reserves instead of public bonds (further results are available from the authors upon request). Indeed, within this model it is rational for banks to demand as many bonds as possible, because they systematically yield a higher return.

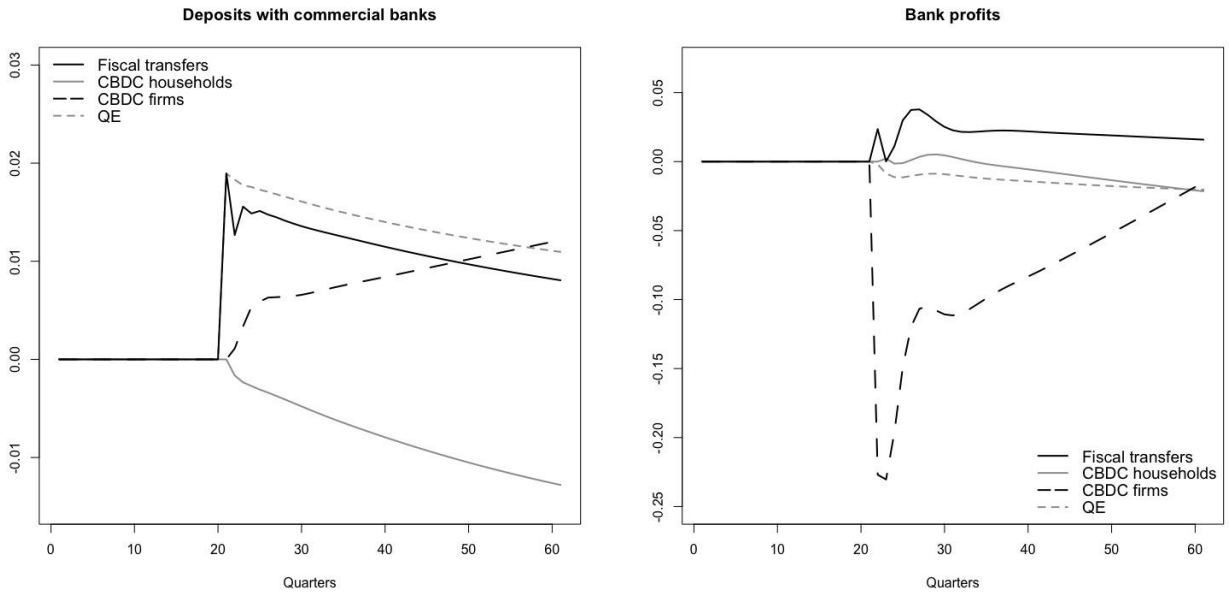
to upper-class households has a larger impact on GDP, it correspondingly implies lower deficit and debt.
In summary, the analysis of public sector finance in the four treatments highlights a trade-off. On the one hand, if the goal of policy makers is to reduce public debt, a CBDC targeted to households seems the most effective tool. On the other hand, if the policy objective (or a hard constraint) is to keep the size of the central bank's balance sheet under control, the issuance of a CBDC targeted to firms seems to provide the best tool.

5.3 - Effects on the banking sector

Concerning the impact of the four treatments on the bank's deposits held by households and on bank profits, we find that an expansionary fiscal policy (treatment 1) induces an increase in households' deposits and, consequently, an increase in the profits of the banking sector, as shown in figure 7. This increase is due to the wealth effect induced by the transfer and, for the upper-class households, it is also sustained by the increased profits of the firms and banks that they own.
With QE too we predict a higher demand for deposits (especially upper-class households' savings deposits) with respect to the baseline (e.g. Choulet, 2015). This is due to the lower amount of government bonds available for purchase by the private sector, once the central bank starts to buy more of them. Following the QE shock, the profits of the commercial banks decrease with respect to the baseline: on their liabilities side this happens because of the higher aggregate costs of deposits; on the asset side, because of the lower return on government bonds. The negative impact of QE on banks' profitability might seem an unrealistic feature of the model. However, it should be noted that the reduction in banks' profits is more than offset by banks' (unrealised) capital gains, generated by asset inflation on the public bonds they own (see table A1). Indeed, there is no consensus in the literature on the effect of QE on bank profits. For example, Altavilla et al. (2017), studying the European case, found no evidence of lower bank profits.
Their empirical analysis shows that, despite the flattening of the yield curve, a positive effect on loan loss provisions and on non-interest income has largely offset the negative effect on net interest income. Demertzis and Wolff (2016) argue that an observed reduction in bank profits is not attributable to QE since the main causes of low bank profitability are to be found in non-performing loans, legal risks, and other issues unrelated to net interest income.
As predicted by many scholars (e.g. Keister and Monnet, 2020; Kim and Kwon, 2021; Keister and Sanches, 2021), we find that a CBDC targeted to households (treatment 2) leads to a progressive reduction in bank deposits with respect to the baseline. Households prefer to hold the CBDC rather than bank deposits, and as banks loose a source of low-cost financing, they buy fewer bonds and therefore suffer from a reduction of their aggregate profits too.
In contrast, in treatment 3 (CBDC to firms), our simulations show a steady rise in the demand for deposits by households, originated by the increase in disposable incomes induced by the higher GDP. Yet, in this treatment bank profits drop even more than in the previous case, due to the lower indebtedness of firms towards the banking sector. In our model, this dynamic has a stronger negative impact on banks' profits than the reduction in households' deposits implied by the previous treatment, because of the model assumption that banks never face liquidity constraints. Should they ever need funding, they could always demand more advances from the central bank at a cost lower than the interest income on their assets. Therefore, the loss of profits in treatment 2 arises from the reduced opportunities for the banks to invest free cash on government bills, and it is proportional to the spread between the interest rate on checking deposits and that on bills. Instead, the loss in treatment 3 arises from the reduced opportunities to lend money, and it is (larger than the previous ones and) proportional to the spread between the interest rate on loans to firms and the alternative uses of liquidity for banks, namely government bills and discretionary reserves.

While the specific assumptions about these interest rate spreads may or may not fit the current situation in a specific country that is considering the introduction of a CBDC, we deem it relevant to highlight that potentially the reduced demand for loans – due to a desire to deleverage instead of using the CBDC for additional expenditures – is at least as relevant a risk for financial stability as the reduced demand for deposits (Bindseil, 2020), even though the former has not yet been adequately discussed in the literature.

Figure 7 – Impact on the banking sector



Notes: for each period, the values shown are ratios to the corresponding value in the baseline scenario minus 1.

In our case, firms did not face liquidity constraints before the shock, and therefore they used the new resources to reduce other loans that they already had, independently of what the central bank intended. Notice that this result is related to the transfer of resources from the central bank, it is a by-product of helicopter money, and it is not a consequence of the transfer taking the form of a loan. This is evident when considering again figure 3: firms transfer their asset (the means of payment) to banks in order to repay their outstanding loans, and they keep the liability vis-à-vis the central bank (the irredeemable loan) on their balance sheet. Had they received the CBDC in the form of a grant, only the composition of the liabilities would have differed (with a higher net capital due to the capital gain from the central bank transfer), but not in the sense of a larger demand for commercial banks' loans, and the assets size would have been the same.

In conclusion, central banks (e.g. Panetta, 2021b) stress that they do not wish to enter into the business of commercial banks; but in so far as a CBDC is perceived to be a substitute for other financial assets or liabilities, this is inevitable.

6 - Conclusions

When Covid-19 hit, most advanced economies had not yet exited from the very expansionary monetary stance made necessary by the global financial crisis and the ensuing euro crisis, several years before. They then embarked in a new round of expansionary policies, further made necessary by the war in Ukraine. On both sides of the Atlantic, central banks are now experimenting ways out and reversals of these monetary expansions, starting with substantial rate increases. Yet, "Quantitative Tightening" is not easily implemented both due to financial stability concerns, in particular its negative impact on financial assets prices, and for the risk of further manufacturing a recession. In this context, the introduction of additional tools in the economic policy mix, and arguably policy tools that might leverage different transmission channels than what are currently used, might be especially advisable.

In this paper we investigated the impact that the introduction of a CBDC could have in a complex advanced economy, by comparing it to more traditional economic policies. We considered four treatments: a fiscal transfer to households; the issuance by the central bank of a CBDC: targeted to households, or targeted to firms' accounts; and Quantitative Easing. Our analysis shows that issuing a CBDC has indeed the potential of activating a new transmission channel for monetary policy, whose effectiveness depends on behavioural patterns (such as firms' desire to reduce their leverage) and on different propagation mechanisms than usually considered (namely, the sensibility of investments and of interest rates to firms' leverage).

Simulation analysis suggests that fiscal transfers might still have the highest immediate impact on GDP, mostly depending on how much the CBDC would be immediately spent. But in the long run, the issuance of a CBDC targeted to households outperforms all treatments considered in terms of impact on GDP, while it has no impact (or even a negative one) on public debt. Yet, this comes at the cost of a more sizeable expansion of the Central Bank's balance sheet than the other traditional policies.

Whereas the impact of a CBDC targeted to households depends on its ability to stimulate consumption demand through wealth effects, the positive impact of QE on GDP (and on banks' profits) is entirely due to asset inflation. We see this as a clear advantage of helicopter money policies over QE.

Both QE and the CBDC targeted to households reduce banks' profits: the former by reducing interest rates, and the latter because of the lower demand for bank deposits. However, our simulations suggest that this impact is on the whole modest (and in the case of QE, it is more than offset by banks' unrealized capital gains). In contrast, the scenario of a CBDC targeted to firms too has a positive impact on GDP, both in the short and in the long run, but it is the scenario with the highest negative impact on commercial banks' profits. This negative impact, on a much larger scale than in the other two scenarios, derives from firms' lower demand for loans, and is such that might realistically pose financial stability challenges. In our analysis, this risk is larger in the case of a CBDC targeted to firms than one targeted to households, mostly because we assume that bank lending to firms is more profitable than alternative available assets for banks. Besides these aspects, however, a main result that emerges from our analysis is that for reasonable ranges, our results do not crucially depend on the model parametrization.

In our model, such a negative impact does not hamper economic growth in the long run, but more detailed models tailored at gauging this specific aspect are certainly needed. As opposed to the single case of an open-ended non-onerous loan to households or firms, that we consider in this work, CBDC injections could be fine-tuned, for example with the application of an interest rate and/or a time limit after which the monetary expansion could be reversed. The precise impact of these design details would better be captured by models calibrated on single countries or specific economies.

Some of the results we obtained are necessary, in the sense that they arise from accounting identities or near-identities, which a SFC model just makes evident. For example, except for specific design

issues that might justify their demand (e.g. easiness of doing international transactions), in general it seems plausible to assume that from the commercial banks' perspective a CBDC is not too different from traditional reserves. Other results were obtained starting from behavioural assumptions that, however, seem to be widely shared in the literature. For example, the expectation is that households might find a CBDC more attractive than bank deposits because of the lower counterparty risk or other similar considerations. Similarly, we assumed that firms would prefer to owe a loan to the central bank than to private banks – which again seems reasonable, as long as the interest rate charged (zero, in our case) is lower than that charged by commercial banks. Therefore, a CBDC constitutes money in a much wider sense than just as a means of payment, and with helicopter money the central bank enters the business of commercial banks regardless of its stated or real intentions.

Moreover, our fairly large SFC model allowed us to show in a comparative way (across policy instruments) that for all policy tools considered here, the transmission channels could be many and sometimes indirect, i.e. involving a long causal chain and positive or negative feedbacks. In this light, a further advantage of CBDCs is the possibility to target specific sectors of the economy as recipients of a monetary injection – be it all or a class of households or firms. CBDCs can thus provide an opportunity e.g. for sterilisation of other policies.

In conclusion, while the risks for financial stability are real (Fernàndez-Villaverde et al., 2021), and in some cases possibly substantial, the debate around the possible introduction of CBDCs should explicitly consider the pros and cons of such move, instead of focusing on the 'defensive' need to pre-emptively tame private market initiatives or the financial innovations in "systemically competitor" countries such as China (Allen et al, 2022).

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Appendix 1 – Additional results

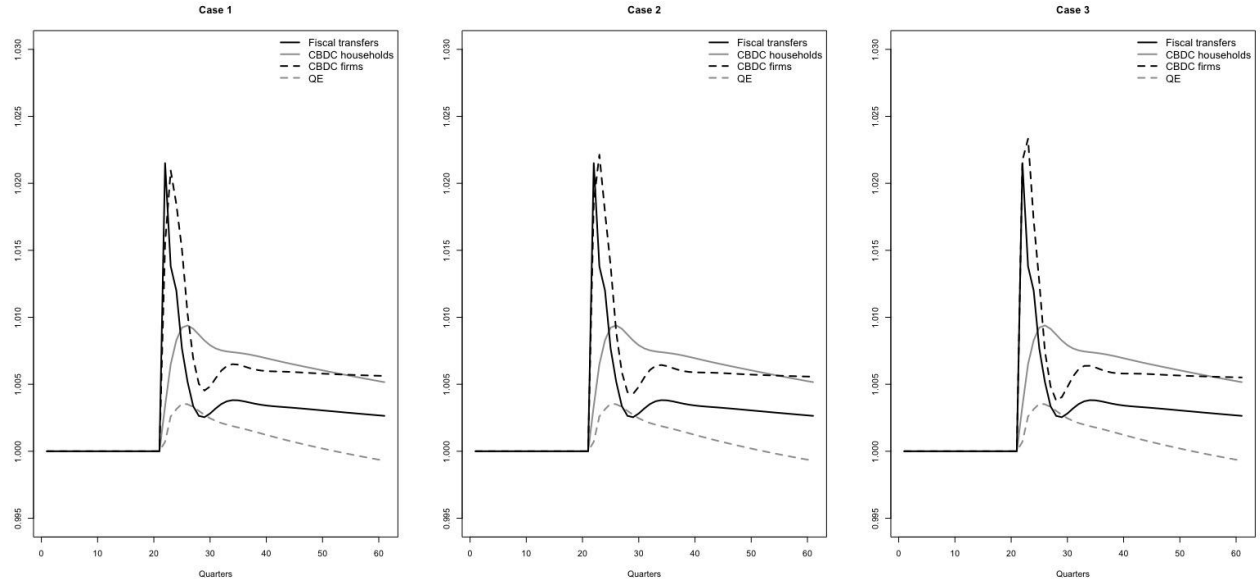
Table A1. Treatments' impact on variables not considered in the main text

	Treatment	Instantaneous impact	Peak impact	Long period impact
Goods price inflation	*1 - Fiscal Transfers*	3.69	3.69	0.69
	2 - CBDC to Households	1.42	1.59	0.29
	3 - CBDC to Firms	2.55	2.62	0.66
	4 - QE	1.09	1.29	0.63
Unemployment	*1 - Fiscal Transfers*	0.67	0.67	1
	2 - CBDC to Households	0.93	0.93	1
	3 - CBDC to Firms	0.8	0.8	1
	4 - QE	0.97	0.97	1
Production firms' EBITDA	*1 - Fiscal Transfers*	1.02	1.02	1
	2 - CBDC to Households	1	1.01	1.01
	3 - CBDC to Firms	1.02	1.02	1.01
	4 - QE	1	1	1
Disposable income of lower class households	*1 - Fiscal Transfers*	1.02	1.09	1
	2 - CBDC to Households	1	1.01	1
	3 - CBDC to Firms	1.02	1.02	1
	4 - QE	1	1	1
Disposable income of upper class households	*1 - Fiscal Transfers*	1.01	1.09	1
	2 - CBDC to Households	1	1.01	1
	3 - CBDC to Firms	0.98	1.03	0.99
	4 - QE	1	1	0.99
Assets price inflation (weighted average of stocks and bonds)	*1 - Fiscal Transfers*	0.96	71.15	1.04
	2 - CBDC to Households	1.69	117.92	1.08
	3 - CBDC to Firms	0.92	302.5	1.13
	4 - QE	16.13	350.79	1.19
Unrealised capital gains for the banking sector	*1 - Fiscal Transfers*	7.64	7.64	4.11
	2 - CBDC to Households	0.25	-6.55	-6.55
	3 - CBDC to Firms	30.43	30.43	29.61
	4 - QE	6.12	6.12	1.86

Note: the table reports values as ratios to the baseline. "Instantaneous impact" denotes the variable value in the quarter immediately after the shock; "peak impact" the value in the period when the absolute distance from the baseline is highest; and "long period impact" the value in the final period of simulation.

Appendix 1.1 – Different assumptions on the model's parametrization

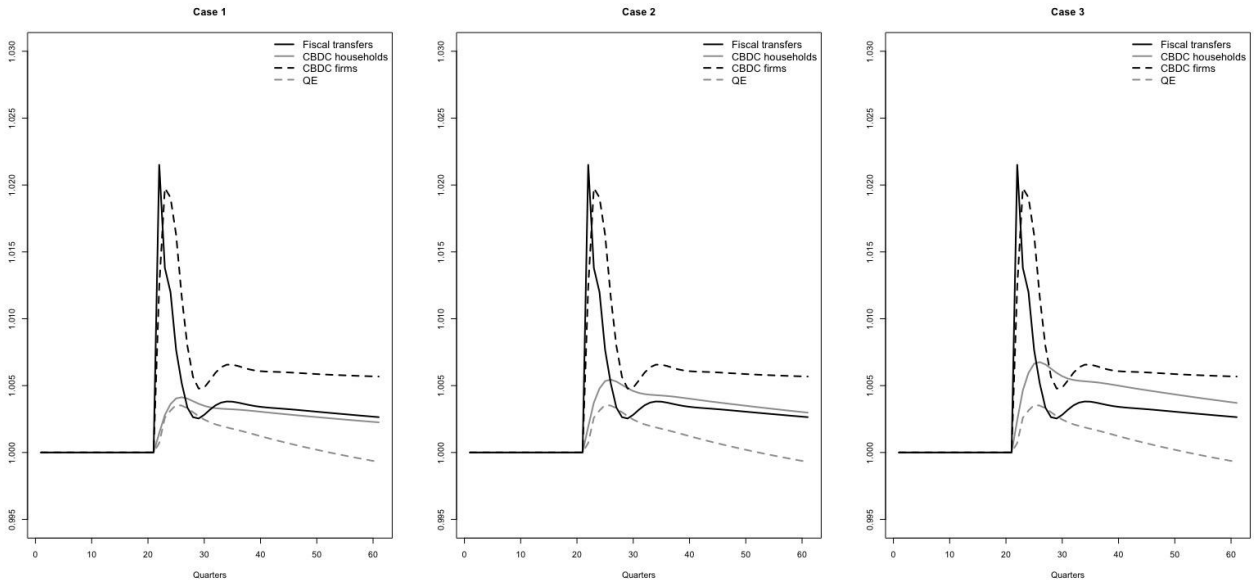
Figure A1. Robustness analysis: Investment induced by CBDC, as a percentage (η) of the CBDC loan.



η = 1% η = 2% η = 3%

Notes: for each period, the values shown are ratios of the corresponding value in the baseline scenario. The parameters considered in the main text are: η = 0%

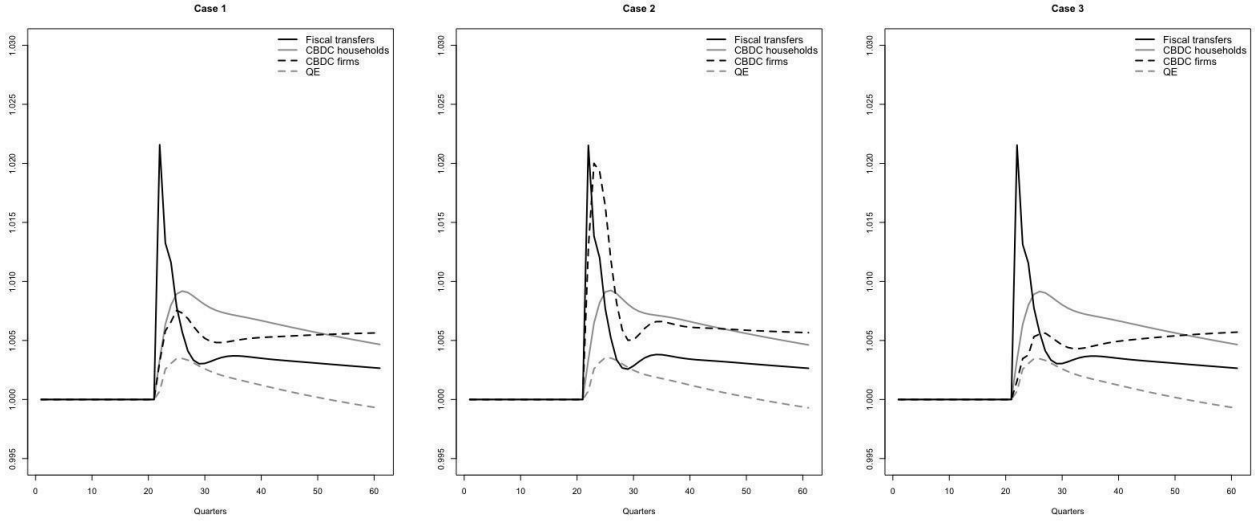
Figure A2. Robustness analysis: MPC CBDC of the lower-class (α_{CBDCl}) and the upper-class (α_{CBDCu})



α_{CBDCl}= 1% α_{CBDCl}= 2% α_{CBDCl}= 3%
α_{CBDCu}= 1% α_{CBDCu}= 2% α_{CBDCu}= 3%

Notes: for *each period, the values shown are ratios of the corresponding value in the baseline scenario. The parameters considered in the main text are:* α_{CBDCl}= *5% and* α_{CBDCu}= *5%.*

Figure A3. Robustness analysis: Elasticity of investment (κ_2) and loan interest rate (μ_{l1}) to leverage



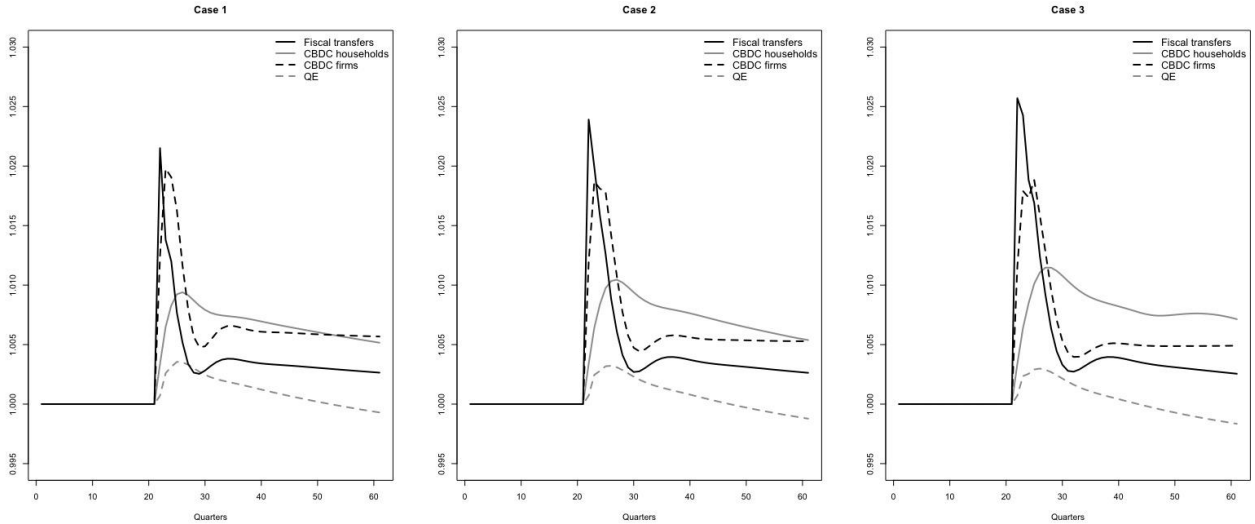
κ_2= -0,2
μ_{l1}= 0,05

κ_2= -0,4
μ_{l1}= 0,05

κ_2= -0,2
μ_{l1}= 0,1

Notes: for each period, the values shown are ratios of the corresponding value in the baseline scenario. The parameters considered in the main text are: κ_2= -0,4 and μ_{l1}= 0,1.

Figure A4. Robustness analysis: MPCY of the lower-class households (α_1) and the upper-class households (α_7).



α_1 = 49,7%
α_7= 15%

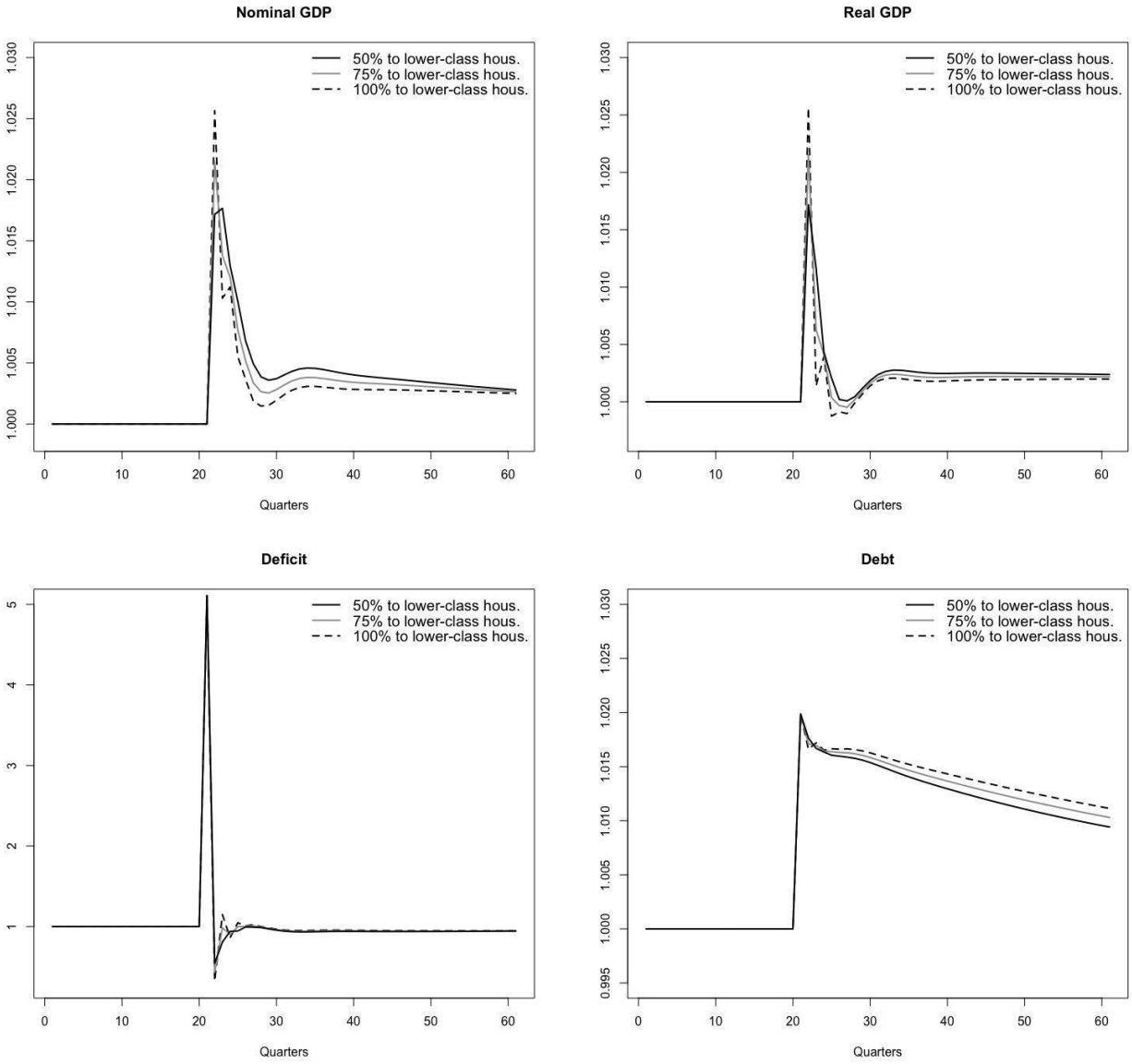
α_1 = 49,7%
α_7= 35%

α_1 = 49,7%
α_7= 49,7%

Notes: for each period, the values shown are ratios of the corresponding value in the baseline scenario. The parameters considered in the main text are: α_1 = 49,7% and α_7 = 15%.

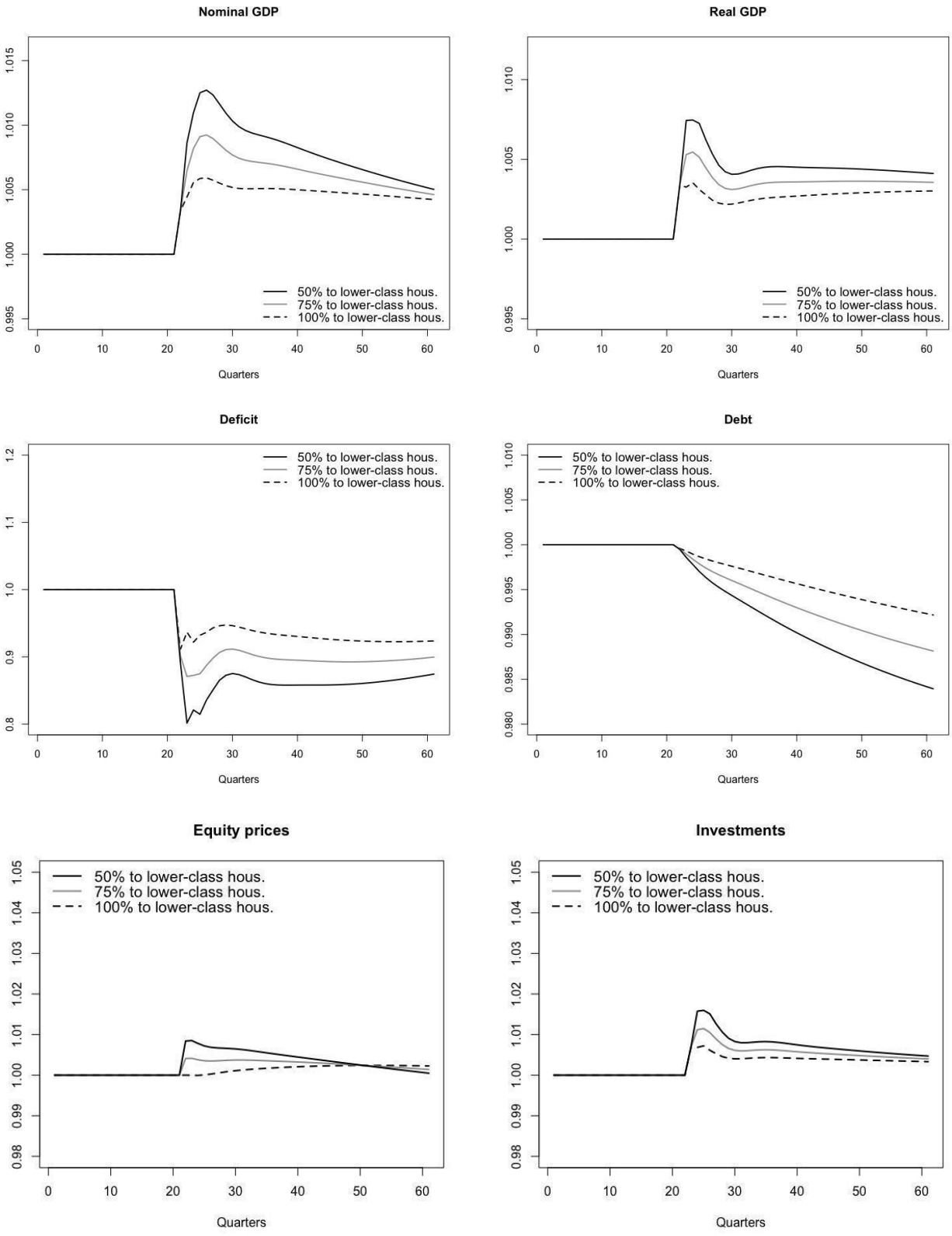
Appendix 1.2 – Further robustness analysis

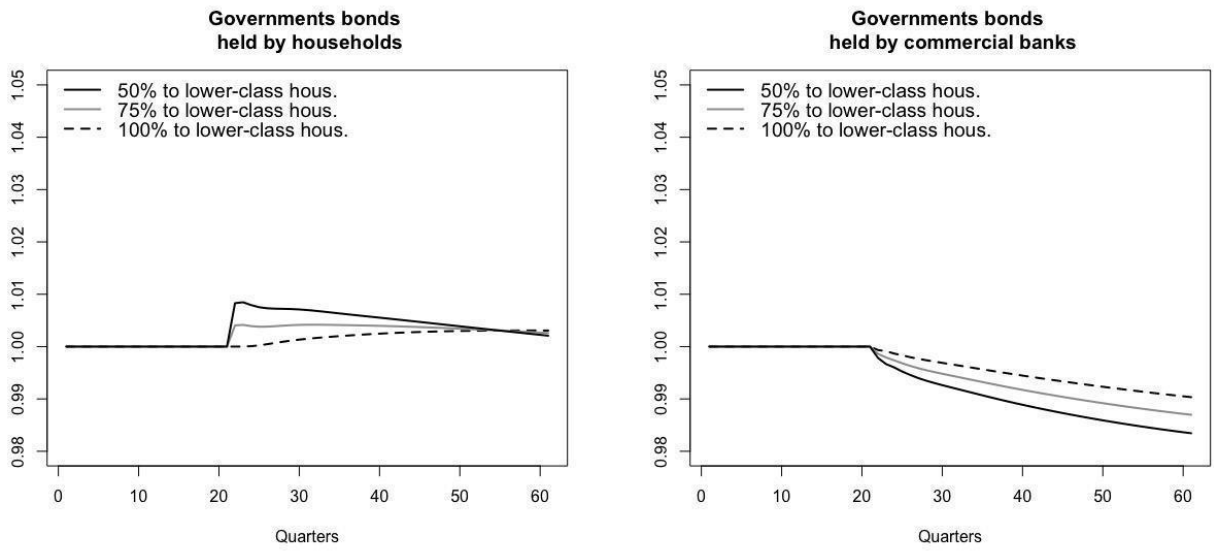
Figure A5. *Targeting of fiscal transfers, and variable shares of fiscal transfers accrued to lower-class and upper-class households in treatment 1.*



Notes: for each period, the values shown are ratios of the corresponding value in the baseline scenario.

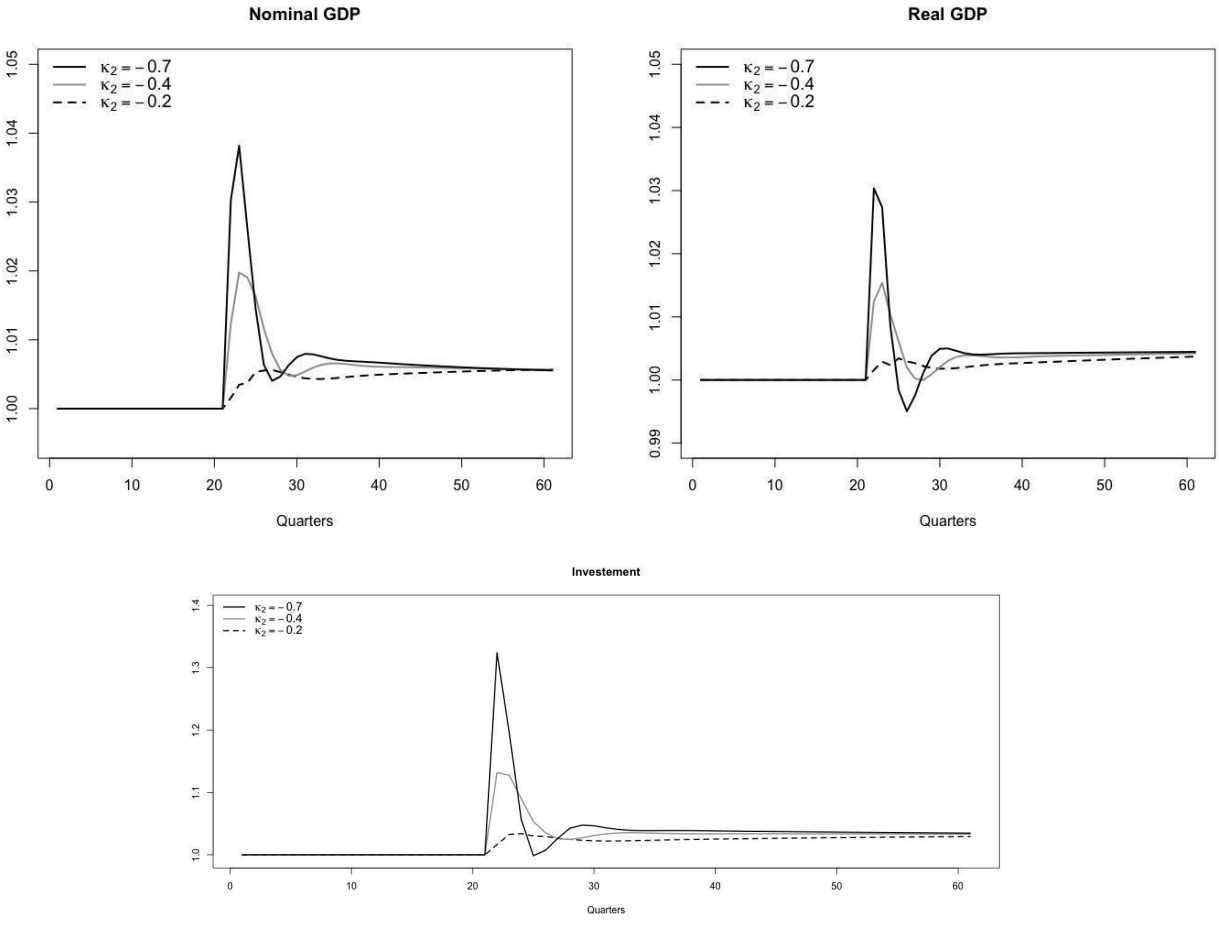
Figure A6. *Targeting of the CBDC and variable shares of the beneficiaries of CBDC between lower-class and upper-class households in treatment 2.*





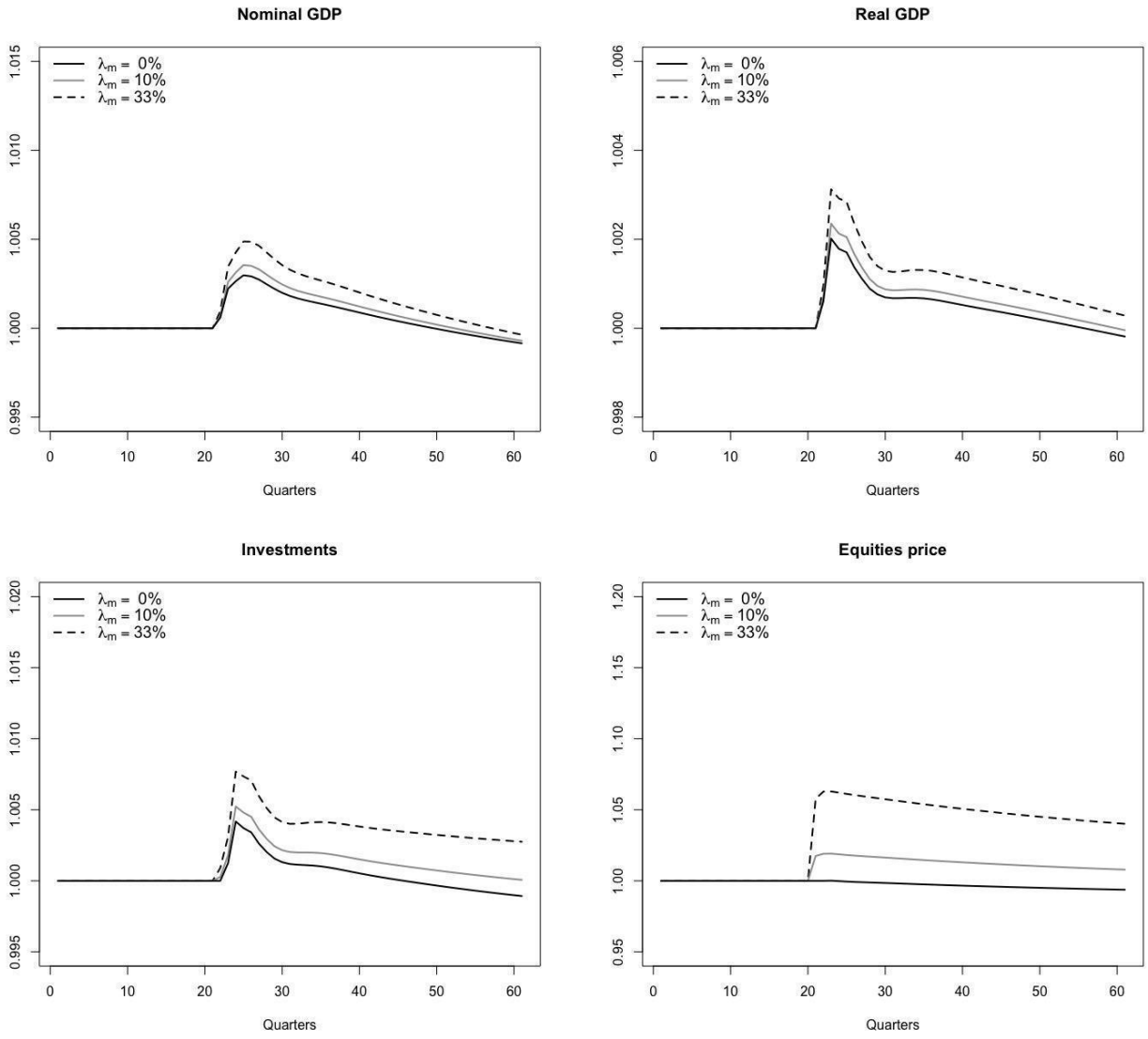
Notes: for each period, the values shown are ratios of the corresponding value in the baseline scenario.

Figure A7. *Varying elasticity of investments to firms' financial leverage in treatment 3.*



Notes: for each period, the values shown are ratios of the corresponding value in the baseline scenario.

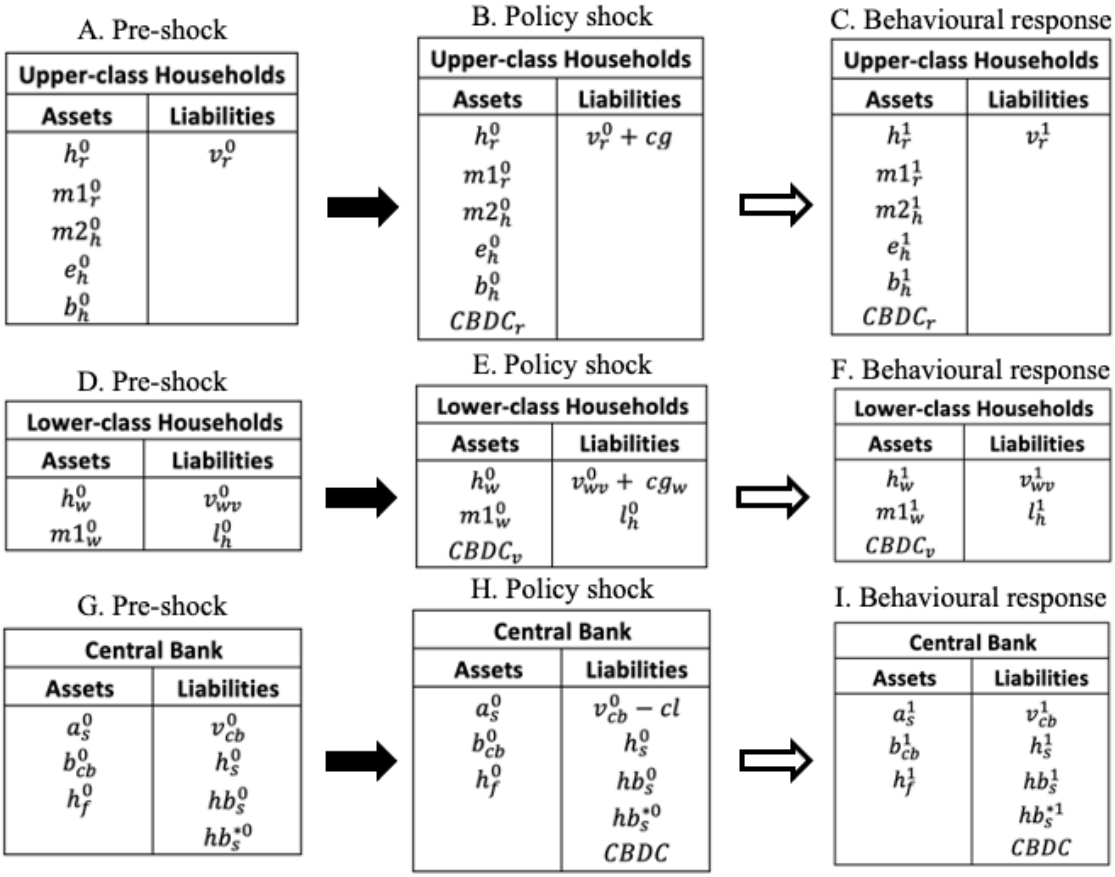
Figure A8. *Variable strategies for households' portfolio reallocations after the QE shock in treatment 4.*



Notes: for each period, the values shown are ratios of the corresponding value in the baseline scenario.

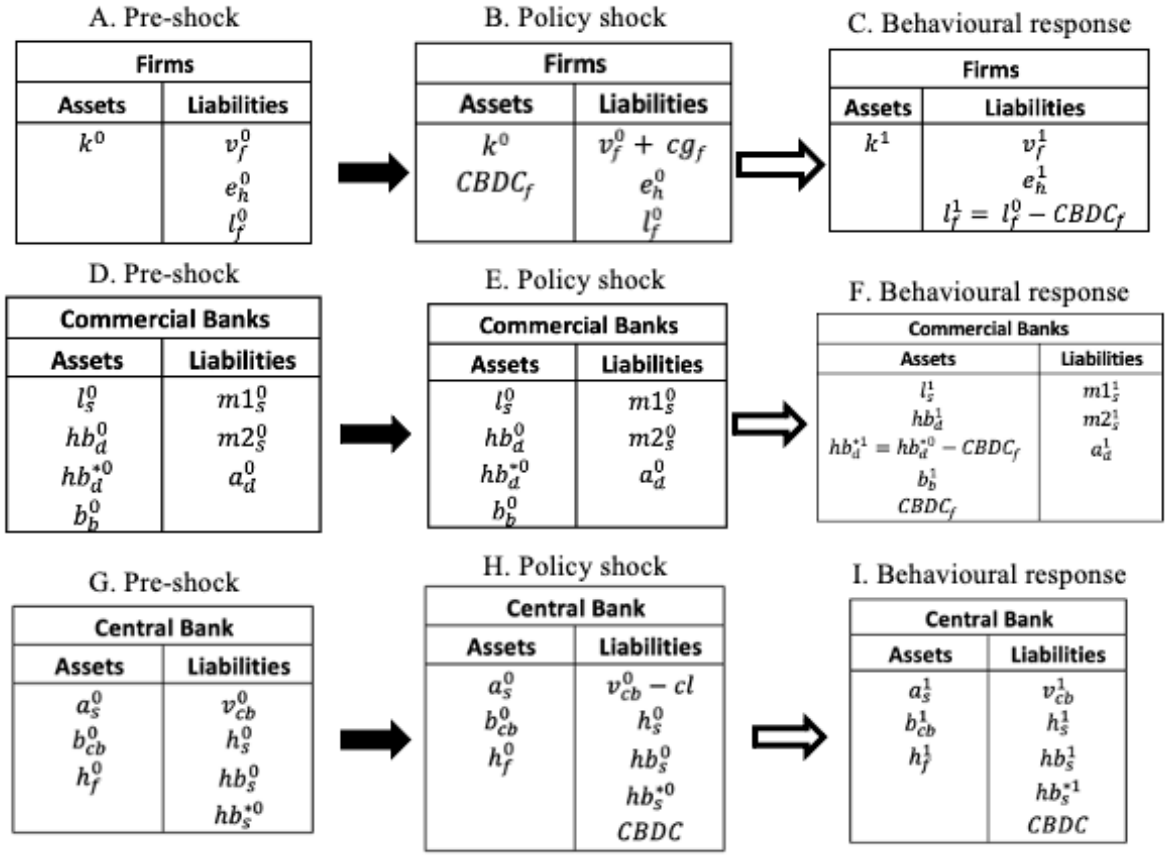
Appendix 1.3 – Balance sheets for treatments 2 and 3 if the Central Bank issues the CBDC as a grant rather than as a loan.

Figure A9 – Treatment 2: balance sheets



Note: cg and cg_w denote capital gains; cl denotes capital loss; superscript 0 denotes values at the beginning of the period, and superscript 1 at the end of the period.

Figure A10 – Treatment 3: balance sheets



Note: cg_f denotes capital gains; cl denotes capital loss; superscript 0 denotes values at the beginning of the period, and superscript 1 at the end of the period.

Appendix 2 – Model specification

Below are reported all the equations of the full model, as modified with respect to Passarella e Sawyer (2021) due to the introduction of a CBDC (R code is available from the authors upon request).

2.1- Non-financial firms

1	$y = c + id + gov + tb$	Aggregate income
2	$k^T = \kappa \cdot \frac{y_{-1}}{E(p)}$	Target stock of capital
3	$da = \delta \cdot k_{-1} \cdot p$	Depreciation allowances
4	$af = da$	Amortisation funds
5	$id = \gamma \cdot (k^T - k_{-1}) \cdot p + da + \eta \cdot CBDC_{f-1} \cdot p$	Investment
6	$\kappa = \kappa_0 + \kappa_1 \cdot q_{-1} + \kappa_2 \cdot lev_{-1}$	Capital-Output ratio
7	$k = k_{-1} + \frac{(id - da)}{p}$	Stock of capital
8	$f_f = y - r_{l-1} \cdot l_f - af - wb$	Firms' profits
9	$fd_f = (1 - \theta) \cdot f_{f-1}$	Dividends
10	$fu_f = f_f - fd_f$	Undistributed firms' profits
11	$l_f = l_{f-1} + id - af - fu_f - (esr - esr_{-1}) \cdot pe - (1 - \eta) \cdot CBDC_f$	Firms' demand for loans
12	$bv = bv_{-1} + (esr - esr_{-1}) \cdot pe$	Firms' equity (book value)
13	$esr = esr_{-1} + \chi \cdot id \cdot pe$	Securities issued by firms
14	$v_f = k - l_f - bv - pass_f$	Firms' net wealth

2.2- Households

15	$yd_l = wb \cdot (1 - \Omega_r) - r_{lh-1} \cdot l_{h-1} + tr_l - tax_l$	Disposable income of lower-class HH
16	$yd_u = wb \cdot \Omega_r + r_{m2-1} \cdot m2_h + tr_u + r_{b-1} \cdot b_h + fd_f + f_b - tax_u$	Disposable income of upper-class HH
17	$yd = yd_l + yd_l$	Total disposable income of households
18	$c_l = \frac{(\alpha_1 \cdot yd_l + \alpha_{rl} \cdot v_l + \alpha_{m1} \cdot m1_l + \alpha_{CBDCl} \cdot att_{l-1}) \cdot p}{p^e} + \alpha_{im} \cdot \left(\frac{c_{l-1}}{c_{u-1}}\right) \cdot p$	Lower-class HH consumption
19	$c_u = \frac{(\alpha_7 \cdot yd_u + \alpha_{ru} \cdot v_u + \alpha_{m1} \cdot m1_u + \alpha_{m2} \cdot m2_h + \alpha_{CBDCu} \cdot att_{u-1}) \cdot p}{p^e}$	Upper-class HH consumption
20	$c = c_l + c_u$	Total consumption
21	$\alpha_1 = \alpha_{10} - \alpha_{11} \cdot r_{lh-1} - \alpha_{12} \cdot un_{-1}$	MPCY of lower-class HH
22	$nv_l = nv_{l-1} + yd_l - c_l$	Lower-class HH net wealth
23	$v_l = nv_l + l_h + pass_l$	Lower-class HH wealth (gross of loans)
24	$v_u = v_{u-1} + yd_u + cg - c_u$	Upper-class HH wealth
25	$v_h = v_l + v_u$	Total household wealth
26	$cg = esr \cdot (pe - pe_{-1})$	Capital gains
27	$cf = m1_{l-1} - l_{h-1} + yd_l - c_l - (h_l - h_{l-1})$	Cash-flow of lower-class HH
28	$(m1_l = cf\ ;\ l_h = 0)$ **if** $(cf \geq 0)$ $otherwise\ (m1_l = 0\ ;\ l_h = -cf)$	Lower-class HH's financial position
29	$\lambda_{CBDC} = \frac{yd_l}{yd}$	Share of CBDC credited to lower-class HH

2.3- Portfolio decisions

30	$ehr = esr$	Equilibrium condition on the securities market
31	$b_h = (\lambda_{10} \cdot v_{u-1} + \lambda_{11} \cdot v_{u-1} \cdot r_{b-1} + \lambda_{12} \cdot v_{u-1} \cdot r_{m-1} + \lambda_{13} \cdot yd_{u-1} + \lambda_{14} \cdot v_{u-1} \cdot r_{e-1}) - qe$	Households' holding of bills
32	$m1_u = (\lambda_{20} \cdot v_{u-1} + \lambda_{21} \cdot v_{u-1} \cdot r_{b-1} + \lambda_{22} \cdot v_{u-1} \cdot r_{m-1} + \lambda_{23} \cdot yd_{u-1} + \lambda_{24} \cdot v_{u-1} \cdot r_{e-1}) + \left(\frac{1-\lambda_m}{e}\right) \cdot qe$	Cheque deposits held by upper-class HH

33	$pe = (\lambda_{30} \cdot v_{u-1} + \lambda_{31} \cdot v_{u-1} \cdot r_{b-1} + \lambda_{32} \cdot v_{u-1} \cdot r_{m-1} + \lambda_{33} \cdot yd_{u-1} + \lambda_{34} \cdot v_{u-1} \cdot r_{e-1}) + \frac{(\lambda_m \cdot qe)}{ehr}$	Shares price
34	$eh = ehr \cdot pe$	Value of shares held by HH
35	$h_l = \lambda_{cl} \cdot c_l \cdot \frac{p^e}{p}$	Lower-class HH s' holding of cash
36	$h_u = \lambda_{cu} \cdot c_u \cdot \frac{p^e}{p}$	Upper-class HHs' holding of cash
37	$h_h = h_l + h_u$	Total cash holding
38	$m1_h = m1_l + m1_u$	Total cheque deposits
39	$m2_h = v_{ru} - h_u - m1_u - b_h - eh - att_u + pass_u$	Saving deposits
40	$b_h^{pot} = b_h + qe$	Households' potential demand for bills (QE scenario)
41	$b_d^{pot} = b_h^{pot} + b_b + b_{cb}$	Total potential demand for bills (QE scenario)

2.4- Commercial banks

42	$l_s = l_f + l_h$	Supply of bank loans
43	$m1_s = m1_h$	Supply of cheque deposits
44	$m2_s = m2_h$	Supply of saving deposits
45	$f_b = r_{l-1} \cdot l_{f-1} + r_{lh-1} \cdot l_{h-1} + r_{b-1} \cdot b_{b-1} - r_{m-1} \cdot m2_{s-1} - r_{a-1} \cdot a_{d-1} + r_{h-1} \cdot (hb_{d-1} - hb_{d-1}^*)$	Banks' profits
46	$hb_d = \rho_1 \cdot m1_{s-1} + \rho_2 \cdot m2_{s-1} + (1-\rho_1) \cdot \left(\frac{1-\lambda_m}{2}\right) \cdot qe + (1-\rho_2) \cdot \left(\frac{1-\lambda_m}{2}\right) \cdot qe$	Required reserves
47	$b_b^{not} = m1_s + m2_s - l_s - hb_d - (1 - \eta) \cdot att_f$	Notional amount of bills held by banks
48	$b_b = b_b^{not} \cdot \beta + \beta_{CBDC} \cdot att_f \; if \; \left(\left(b_b^{not} \cdot \beta + (1 - \eta) \cdot \beta_{CBDC} \cdot att_f\right) \leq (b_s - b_h) \right)$ $otherwise \; (b_b = b_s - b_h)$	Bills held by banks
49	$hb_d^* = b_b^{not} \cdot (1-\beta) - (1 - \eta) \cdot \beta_{CBDC} \cdot att_f \; if \; \left(\left(b_b^{not} \cdot \beta + (1 - \eta) \cdot \beta_{CBDC} \cdot att_f\right) \leq (b_s - b_h) \right)$ $otherwise \; (hb_d^* = b_b^{not} - b_b)$	Banks' discretionary reserves
50	$a_d = 0 \; if \; (b_b^{not} > 0)$ $otherwise \; (a_d = -b_b^{not})$	Demand for advances

2.5- Government

51	$tax_l = \tau_1 \cdot wb \cdot (1 - \Omega_r) + \tau_3 \cdot m1_l$	Taxes paid by lower-class HH
52	$tax_u = \tau_0 + \tau_1 \cdot wb \cdot \Omega_r + \tau_2 \cdot \left(r_{m-1} \cdot m2_h + r_{b-1} \cdot b_h + fd_f + f_b\right) + \tau_3 \cdot (v_{u-1} - h_{u-1} - pass_{u-1})$	Taxes paid by upper-class HH
53	$tax = tax_l + tax_u$	Total tax revenue
54	$gov = \sigma_0 + \sigma_1 \cdot y_{-1}$	Government spending
55	$def = tr + gov + r_{b-1} * b_{s-1} - tax - f_{cb}$	Government deficit
56	$b_s = b_{s-1} + def$	Bills issued

2.6- Foreign Sector

57	$im = exp\,(m_0 + m_1 \cdot log\ log\ (exr_{-1}) + m_2 \cdot log\ log\ (y_{-1}) + m_3 \cdot log\ log\ (p_{-1}))$	Imports
58	$x = exp\,(x_0 + x_1 \cdot log\ log\ (exr_{-1}) + x_2 \cdot log\ log\ (yF_{-1}) + m_3 \cdot log\ log\ (p_{-1}))$	Exports
59	$yF = yF_{-1} \cdot (1 + gF)$	Aggregate foreign income
60	$gF = gF_{-1} \cdot (1 - gS)$	Foreign income growth rate
61	$tb = x - im$	Trade balance
62	$fr = fr_{-1} + tb$	Foreign reserves

2.7- Central Bank

63	$b_{cb} = b_s - b_b - b_h$	Bills held by the Central Bank

64	$hb_s = hb_d$	Supply of required reserves
65	$hb_s^* = hb_d^*$	Supply of discretionary reserves
66	$h_s = b_{cb} + a_s - \left(hb_s + hb_s^* + att_l + att_u + att_f\right) + fr + pass_l + pass_u + pass_f$	Supply of cash
67	$a_s = a_d$	Supply of advances
68	$f_{cb} = r_{b-1} \cdot b_{cb-1} + r_{a-1} \cdot a_{s-1} - r_{h-1} \cdot (hb_{s-1} + hb_{s-1}^*)$	Central Bank's profit

2.8- Interest rates

69	$r_e = \frac{fd_f + cg}{eh_{-1}}$	Return rate on firms' securities
70	$r_b = r^* + \mu_b$	Return rate on bills
71	$r_l = r^* + \mu_l$	Rate of interest on loans to firms
72	$r_{lh} = r^* + \mu_{lh}$	Interest rate on loans to HH
73	$r_m = r^* + \mu_m$	Rate of interest on saving deposits
74	$r_a = r^* + \mu_a$	Rate of interest on Central Bank advances
75	$r_h = r^* + \mu_h$	Rate of interest on reserves
76	$\mu_l = \mu_{l0} + \mu_{l1} \cdot lev_{-1}$	Mark-up: loans' interest rate
77	$b_{pr} = \frac{b_d^{pot}}{b_s}$	Potential private demand for bills over supply
78	$\mu_b = \mu_{b0} - \mu_{b1} \cdot b_{pr-1}$	Mark-up: bills' return rate

2.9- Labour market

79	$wb = w \cdot n_d$	Wage bill
80	$n_d = \frac{y}{(pr_f \cdot p)}$	Labour demand
81	$n_s = n_{s-1} \cdot (1 + gl) + nu \cdot (n_{d-1} - n_{s-1})$	Labour supply
82	$un = 1 - \frac{(n_d + n_g)}{n_s}$	Unemployment rate
83	$wh = wh_0 \cdot wh_1 + (1 - wh_1) \cdot \left[\left(1 - \Omega_1 \cdot (un_{-1} - nun)\right) \cdot (1 + pi^e) \cdot wh_{-1}\right]$	Wage rate of skilled workers
84	$w = \beta_w \cdot w_l + (1 - \beta_w) \cdot wh$	Average wage rate
85	$w_l = \rho_l \cdot w$	Minimum wage rate

2.10- Prices and expectations

86	$pf = \frac{w}{pr_f} \cdot \left(1 + \mu_p\right)$	Unit price of private output
87	$p = pf$	General price level
88	$pi = \frac{p}{p_{-1}} - 1$	Inflation rate
89	$pi^e = \psi_1$	Expected inflation rate
90	$p^e = p_{-1} \cdot (1 + pi^e)$	Expected price level

2.11- Minsky variables and indices

91	$q = \frac{esr * pe + l_f + pass_f}{p \cdot k}$	Valuation ratio (Tobin q)
92	$lev = \frac{l_f}{l_f + v_f + bv}$	Leverage ratio of firms

2.12- Redundant equation

93	$h_h = h_s$	Total holdings of cash

2.13- Scenarios:

2.13.1- Fiscal Transfers

94a	$tr = 0{,}05 \cdot y_{-1}$	Total transfers

95a	$tr_w = \beta_{tr} \cdot tr$	Transfers to lower class households
96a	$tr_r = (1 - \beta_{tr}) \cdot tr$	Transfers to upper class households

2.13.2- CBDC to households

94b	$CBDC = 0{,}05 \cdot y_{-1}$	Central Bank Digital Currency issued
95b	$CBDC_l = \lambda_{CBDC} \cdot CBDC$	CBDC credited to lower class households
96b	$l_{CBDCl} = CBDC_l$	CBDC-related loans to lower-class households
97b	$CBDC_u = (1 - \lambda_{CBDC}) \cdot CBDC$	CBDC credited to upper class households
98b	$l_{CBDCu} = CBDC_u$	CBDC-related loans to upper-class households
99b	$pass_l = pass_{l-1} + CBDC_l$	Lower-class HHs' stock of CBDC-related loans
100b	$att_l = pass_l$	Lower-class HHs' stock of CBDC
101b	$pass_u = pass_{u-1} + CBDC_u$	Upper-class HHs' stock of CBDC-related loans
102b	$att_u = pass_u$	Upper-class HHs' stock of CBDC

2.13.3- CBDC to firms

94c	$CBDC = 0{,}05 \cdot y_{-1}$	Central Bank Digital Currency issued
95c	$CBDC_f = CBDC$	CBDC credited to firms
96c	$l_{CBDCu} = CBDC_u$	CBDC-related loans to firms
97c	$pass_f = pass_{f-1} + CBDC_f$	Firms' stock of CBDC-related loans
98c	$att_f = pass_f$	Firms' stock of CBDC

2.13.4- Quantitative Easing

94d	$\lambda_m = 0{,}1$	Portfolio readjustment toward equities (share)
95d	$QE = 0{,}05$	QE program as a share of previous quarter's GDP
96d	$qe = QE \cdot y_{-1}$	Size of the QE program

Appendix 3 – Parameter values

Symbol	Value	Parameter
α_1	endogenous	Propensity to consume out of income of lower class households
α_{10}	1.5	Autonomous component of the propensity to consume of LC households
α_{11}	25	Sensitivity of the propensity to consume to the interest rate
α_{12}	0.05	Sensitivity of the propensity to consume to the unemployment rate
α_7	0.2	Propensity to consume out of income of upper class households
α_{CBDCu}	0.02	Propensity to consume the CBDC for upper class households
α_{CBDCl}	0.02	Propensity to consume the CBDC for lower class households
α_{im}	1.5	Imitative component of consumption
α_{m1}	0.01	Propensity to consume out of wealth: cheque deposits for households
α_{m2}	0.01	Propensity to consume out of wealth: savings deposits for households
α_{ru}	0.02	Propensity to consume out of wealth for the upper class households
α_{rl}	0.03	Propensity to consume out of wealth for the lower class households
β	0.3	Share of notional bills held as bills by banks
β_{tr}	end.	Share of fiscal transfers to lower-class households
β_w	0.1	Percentage of low skilled workers to total workers
χ	0.1	Target percentage of investment to be funded by share issues
δ	0.1	Depreciation rate
γ	0.2	Reaction speed of adjustment of capital to its target value
κ_0	1.1	Autonomous capital-output ratio
κ_1	0.01	Sensitivity of capital-output ratio to Tobin's *q*
κ_2	-0.3	Sensitivity of capital-output ratio to leverage ratio
η	0	CBDC-induced investment (as a share of CBDC loan)
λ_{10}	0.15	Parameter in portfolio equation of bills
λ_{11}	0.2	Parameter in portfolio equation of bills
λ_{12}	0	Parameter in portfolio equation of bills
λ_{13}	-0.1	Parameter in portfolio equation of bills
λ_{14}	0	Parameter in portfolio equation of bills
λ_{20}	0.4	Parameter in portfolio equation of cheque deposits
λ_{21}	-0.05	Parameter in portfolio equation of cheque deposits
λ_{22}	0	Parameter in portfolio equation of cheque deposits
λ_{23}	0.2	Parameter in portfolio equation of cheque deposits
λ_{24}	0	Parameter in portfolio equation of cheque deposits
λ_{30}	0.1	Parameter in portfolio equation of firms' securities
λ_{31}	-0.15	Parameter in portfolio equation of firms' securities
λ_{32}	0	Parameter in portfolio equation of firms' securities
λ_{33}	-0.1	Parameter in portfolio equation of firms' securities
λ_{34}	0	Parameter in portfolio equation of firms' securities
λ_{CBDC}	end.	Share of CBDC credited to lower-class households
λ_{cu}	0.18	Cash to consumption ratio of upper-class households
λ_{cl}	0.18	Cash to consumption ratio of lower-class households
λ_m	0.1 (in QE)	Portfolio readjustment toward equities (share)
μ_a	0.005	Mark-up: CB advances' return rate
μ_b	end.	Mark-up: bills' return rate
μ_{b0}	0.01	Coefficient of bills' return rate
μ_{b1}	0.01	Coefficient of bills' return rate
μ_{b2}	0.015	Coefficient of bills' return rate
μ_h	-0.01	Mark-up: reserves' return rate
μ_l	end.	Mark-up: loans' interest rate
μ_{l0}	0.02	Coefficient of loans' interest rate
μ_{l1}	0.1	Coefficient of loans' interest rate
μ_{lh}	0.02	Mark-up: interest rate on mortgages

μ_m	0	Mark-up: saving deposits' return rate
μ_p	0.3	Mark-up over labour cost
Ω_1	0.3	PC coefficient: speed of adjustment of un to nun
Ω_r	0.1	Managers' share of wage and salaries
ψ_1	0.03	Coefficient of price expectations function
ρ_1	0.025	Reserves to cheque deposits parameter
ρ_2	0.005	Reserves to saving deposits parameter
ρ_l	0.35	Ratio of low wage rate to high wage rate
σ_0	1.5	Autonomous component of government spending
σ_1	0.25	Dependent component of government spending
τ_0	0.1	Autonomous component of tax revenue
τ_1	0.4	Tax rate on labour income
τ_2	0.3	Tax rate on capital income
τ_3	0.01	Tax revenue rate on wealth
θ	0.04	Profit retention rate
g_F	0.075	Foreign income growth rate
g_l	0.014	Structural rate of growth of labour force
g_S	0.3	De-growth rate of income growth rate
m_0	-2.1	Coefficient of import function
m_1	-0.5	Coefficient of import function
m_2	0.5	Coefficient of import function
m_3	0	Coefficient of import function
nun	0.09	Non-inflationary rate of unemployment
QE	0.05	Size of the QE program
r^*	0.02	Policy rate
wh_0	3	Initial value of skilled workers wage rate
wh_1	0.1	Inertia coefficient of skilled workers wages
x_0	-2.5	Coefficient of export function
x_1	0.5	Coefficient of export function
x_2	0.75	Coefficient of export function
x_3	0	Coefficient of export function