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The distributive impact of unconventional monetary policies – old and new

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Abstract
In this paper we analyze the impact of less conventional monetary policy tools on the personal and functional distribution of income. We focus on the issuance of central bank digital currency (CBDC) in a comparative perspective, using a stock-flow consistent model of the eurozone economy. We consider two kinds of policies: helicopter money policies such as Quantitative Easing and the issuance of a CBDC; and scenarios not based on balance sheet expansions, such as an interest rate policy following the Pasinetti Rule, or a sterilized issuance of CBDC. Monetary policies using CBDCs tend to increase the wage share at the expense of financial rents. The targeted issuance of CBDCs to firms might produce an increase in GDP, corporate profits, and the wage share. The Pasinetti Rule reduces personal income inequality the most, but if applied mechanically, its impact on growth is also the least desirable.

Keywords: Inequality; Monetary policy; Central Bank Digital Currencies; Pasinetti Rule
JEL codes: E5; G0; E12; I3

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After a period of relative tranquility during the "great moderation", central bankers have had to considerably speed up the rate of their innovations. Policies once considered as "unorthodox", such as quantitative easing (QE), have been enacted for so many years that they should probably be seen as the new normal. Against this backdrop, in this paper we analyse the distributional impact generated by a set of so-to-say unconventional monetary policy operations, in the sense that they differ from the 'once traditional' regulation of the interest rate, in many countries, within the framework of an inflation targeting regime.

We consider some already implementable or implemented such policies: some older and now in disgrace, such as (influence on) commercial banks' reserves policy; some newer but now established, like QE; and some already proposed a few years ago but yet untested, such as heterodox monetary policy rules. But mostly, we focus here on the more recent proposal of a specific new policy instrument, namely the issuance of a central bank digital currency (CBDC). A CBDC is an electronic form of money that is a direct liability of the central bank, and as such it differs from other forms of electronic money such as, e.g., bank deposits.

Although it is still just a plan (or a small-scale experiment, in few countries), CBDC has already spurred a burgeoning literature. Yet, the bulk of the debate has narrowly focused on payment systems. Even within macroeconomics, authors and official institutions have discussed almost only two topics around CBDC: the potential for digital transactions, and the risks for financial stability. To our knowledge, this is the first investigation of the possible impact of CBDC on income distribution and inequality.

We focus on the eurozone economy and we compare a baseline scenario, broadly reflecting the long-term dynamics of the currency area from the creation of the euro (in 1999) up to right before the covid shock (2019), with a number of theoretical counterfactuals based on simulations using a calibrated stock-flow consistent (SFC) model adapted from Sawyer and Veronese Passarella (2021) and Temperini et al. (2024).

We introduce in the model three scenarios in which the central bank expands its balance sheet through a direct injection of monetary base (through QE or a CBDC) to households and/or firms; and three scenarios in which the central bank does not immediately expand its balance sheet, although this can then happen as a consequence of the behavioural response of firms, households, or banks. The difference is relevant to distinguish instances of clearly expansionary monetary policy from policies that do not necessarily primarily aim at stimulating economic activity. Issuance of a CBDC appears in both groups of policies, because it could be implemented as a form of helicopter money (with an outright transfer of purchasing power from the central bank to the private sector[4]) or it could be 'sterilized', e.g. by reducing other forms of supply of monetary base (e.g. banknotes and coins in circulation, or other direct liabilities of the central bank).

We refer to other articles in this special issue, and especially to Kappes (2023) for a recent and comprehensive review of the effects that monetary policy can have on the distribution of income. In the next section we will briefly recall only the relevance of considering both direct and indirect effects, to highlight the rationale for our distinction between expansionary monetary policies and other kinds of policies. Except for the (vast) debate on QE, the bulk of the literature has focused on interest rate policy. We try here to widen the scope of this reflection by considering an array of less conventional policies.

Post-Keynesians in particular have actively contributed to this debate, including with proposals on alternative interest rate rules. Among the three main heterodox monetary policy rules within the "parking-it view", we consider in our simulations the Pasinetti Rule

[4] In this case, the CBDC should probably be considered a hybrid instrument, both a monetary and a fiscal policy tool (Temperini et al, 2024).

(for a discussion on monetary policy rules see Rochon and Seccareccia, 2023). We stress from the onset that, due to the artificial environment of computer simulations and in order to maintain the comparability across scenarios and with the baseline, we model the Pasinetti Rule as a mechanic, fixed rule applied by the central bank. We are aware that its proponents (e.g. Lavoie and Seccareccia, in this issue) rather suggest that central banks adopt it flexibly and over a medium-to-long run. Therefore, this policy scenario in our work should rather be seen as an extreme hypothesis, but perhaps indicative of the direction of some trends that might emerge.

With our SFC model, we contribute to the debate with a focus on the eurozone as an aggregate (thus abstracting from issues of geographical imbalances within the currency area), with respect to both functional income inequality – considering the GDP shares of labour and capital incomes – and personal income inequality.

After a brief discussion on the distributive impact of monetary policy, in the following section we first summarize the debate on the issuance of digital currency. Since among those considered here this is the least well known (indeed, in Western countries it is still just a plan), we believe that readers might benefit from some more details before moving to the simulations. We then present our model, the baseline parametrization, and the six policy scenarios; and we finally consider the main counterfactual analyses. As it turns out, our simulations show that the Pasinetti Rule is the most effective policy scenario in terms of reducing inequality, but also the least effective in terms of GDP growth; in contrast, the issuance of CBDC appears to hold the potential for long-term positive impacts, but the details of its issuance will matter significantly.

1. Literature Review

1.1. Inequality and monetary policy

Due to secular stagnation, or even just the global financial crisis of 2007-2009, the 2010-2015 euro crisis, and the pandemic, the central banks of the G7 countries and elsewhere had several reasons to employ unconventional monetary policies on a large scale. As a consequence, since these events there has been a growth in the literature focusing on the effects of monetary policy on income and wealth distribution (Davtyan, 2023; Dolado et al., 2021; Kappes, 2023; Saiki and Frost, 2020; Mumtaz and Theophilopoulou, 2020).

As noted by Rochon and Seccareccia (2023), there are essentially two channels through which monetary policy can impact on inequality: the income channel, and the wealth channel. On the one hand, post-Keynesians typically emphasise that a change in the interest rate has a strong impact on the income generated by securities held by households. This immediately produces a stratification due to the difference between households whose income is derived mainly from wages and those who rely more on financial income. Another important difference emerges between debtor and creditor households, in addition to the fact that financial contracts can be either fixed- or variable-rate. Changes in interest rates, at the same time, could also have an impact on bank credit conditions, and therefore on the level of employment and, ultimately, the income of low wage households or those who become able to find employment. This income channel is considered larger by the (mostly mainstream) authors who hold that reductions in interest rates effectively stimulate aggregate demand. Overall, the income channel works in the direction that an expansionary monetary policy reduces inequality.

On the other hand, the wealth channel focuses on the change in the market value of financial

and real assets held by households. This channel is more relevant, the greater the stock of wealth held by a household. By potentially producing asset price inflation, through the wealth channel an expansionary monetary policy can increase wealth inequality (and possibly income inequality, if one considers capital gains). However, if increased wealth (at least measured at nominal market values) should stimulate more consumption, then the increase in demand and employment should at least partly offset the negative impact on income inequality.

With both channels, the key to an impact of monetary policy on income and/or wealth inequality appears to be the degree of heterogeneity among households, for the direct effect, and the distribution of the benefits from growth, for the indirect effect. Arguably, which channel prevails will at least partly be an empirical question.

Focusing on the eurozone countries over the 2001-2015 period, Guerello (2018) uses a VAR model to study the effects of expansive conventional and unconventional monetary policies on income inequality. In normal times, a reduction in the short-term interest rate is found to generate a reduction in income inequality. In the case of non-conventional monetary policies, the outcome critically depends on the heterogeneity across countries of the ratio between the value of deposits and the value of total financial assets. For countries characterized by a low ratio, unconventional monetary policies increase income inequality, while for countries with a high ratio the opposite occurs. The main explanation for this finding is that a high proportion of deposits necessarily implies a smaller proportion of assets that appreciate following a central bank balance sheet expansion. Casiraghi et al. (2018) study the effect of QE on the distribution of wealth and income of Italian households. Their analysis shows that low-income households have benefited from the positive effect on employment and GDP. Regarding wealth, they find that the effect on inequality is negligible given a balance between the lowering of the remuneration of financial assets and the increase in earned income and capital gains. Lenza and Slacalek (2018) analyze the impact of QE on the distribution of income and wealth for France, Germany, Italy, and Spain in the period 1999-2016. Combining a VAR model with simulations on household microdata, they find that unconventional monetary policy has little or no effect on wealth inequality. As for the distribution of income, the increase in earnings for the lower-income households reduces inequality. Samarina and Nguyen (2019) investigate the impact of monetary policy on income inequality in 10 countries over the period 1999–2014. They consider two channels through which ECB policy can affect income distribution: a financial channel and a macroeconomic channel. The former is captured by capital gains and returns on securities, while the latter by wages and the employment rate. Weighing the relevance of the two effects, the authors find a prevalence of the macroeconomic channel over the financial one.

In the European case (but arguably elsewhere too) a noteworthy channel of interest is that, as a result of both conventional and unconventional monetary policies, inflation of both financial and real assets has been substantial. This process has been found to yield heterogeneous effects on inequality in different countries of the eurozone, in proportion to the different rates of homeownership (Battistini et al., 2022). However, Coibon et al. (2017) find that high-income households benefited more from the rise in shares prices, in this way increasing wealth and income inequality among households.

1.2. The debate on CBDC

Innovation in monetary policy has not been lacking in the last two-three decades, but a

particular boost has been provided by the emergence of private “currencies” or rather financial assets by that name. This has created a sort of competition, that is inducing central bank to accelerate the rate of innovation in monetary matters (Gorton and Zhang, 2023).
Several first and second-generation cryptocurrencies have the ostensive objective of a radical change of the international monetary system, and it is fair to say that they have completely failed at this goal (Fama et al., 2023; Fantacci, 2019). However, this competition has pushed central banks to reflect on how to adopt new technologies in the issuance of money (BIS, 2023). Pilot projects are already underway: primarily the digital yuan, which is already operating, followed the by project of a digital euro, now in a “preparation phase” since November 2023 (ECB, 2023; Cipollone, 2023; Cipollone, 2024).
Although CBDCs are a newly developed instrument, there has been a real flowering of this literature in less than ten years. Several contributions have debated the effects of the issuance of CBDC and its implications (Chen and Siklos, 2022; Meaning et al., 2018; Bordo and Levin, 2017). The main debates in this literature are the impact on the banking system (Auer et al, 2024; Kim and Kwon, 2023), the targeting of monetary aggregates (Chen and Siklos, 2022), and the implications for systemic risk and financial stability (Keister and Sanches, 2023; Chiu et al., 2019). The bulk of this literature belongs to the mainstream of the profession, and perhaps unsurprisingly it focuses on the function of CBDC (and traditional money) as a means of exchange. Specifically, CBDCs allow direct payments among users, like banknotes do, not necessarily intermediated by banks.
For example, Fernández-Villaverde et al. (2021) ask how would the banking system change with the introduction of a CBDC? In their view, the main function of the banking system is to allow maturity and risk transformation and reduce the information asymmetry problems that arise in the debtor-creditor relationship in a disintermediated system. By exploiting economies of scale and scope, banking intermediaries can profitably carry out lending and deposit-taking activities. Since the CBDC is a central bank debt, it will always be considered a safer asset than a bank deposit by the economic agents. However, considering that demand deposits tend to be covered by insurance, it would seem that the difference between bank deposits and a CBDC might not be very considerable.
This conclusion is easily disputed if one considers a systemic crisis or if the central bank issues an interest bearing CBDC. In such a case, to avoid a deposit flight, banks should increase the interest rate on their deposits to at least match the rate offered by the central bank, corrected for the higher risk (Chiu et al., 2023, Keister and Sanches, 2023).
Regarding market structure, a CBDC would break down the oligopoly rent in the banking market (Agur et al., 2022). The money creation capacity of commercial banks could be significantly reduced, at least if the central bank does not introduce a limit to the amount of CBDC within the system.
Specifically, Williamson (2022) studied the role a CBDC can play as a safe asset and their endemic scarcity (Gorton and Zhang, 2023; Amato et al, 2023). Safe assets are used in daily market operations as collateral, and are crucial for the efficient functioning of the financial system. But the introduction of a CBDC could significantly mitigate this problem.
Analyzing data for Italian banks between June 2021 and March 2023, Auer et al. (2024) show how the overall impact of the introduction of a CBDC on bank funding could be mitigated by the inclusion of an individual holding limit combined with stable funding for banks. In this context, the biggest problem would be for bank intermediaries characterized by low excess reserves, making them vulnerable to liquidity shocks.
Papers analyzing the macroeconomic effects of CBDC tend to follow a mainstream approach too, using DSGE or neo-monetarist models (e.g. Burlon et al., 2022; Cova et al., 2022; Assenmacher et al., 2023). To the best of our knowledge, only Temperini et al. (2024) and

Lagoarde-Segot and Revelli (2023) use post-Keynesian models.
Not very popular are considerations for the possible role of CBDC as a store of value, rather than just as a means of payment. This is our focus here, and our first premise is that the real innovation in the launch of an *e*-euro is not the technological aspects of digital paperless money (which is already largely a reality, e.g. with credit cards) but rather the creation of an entirely new class of financial assets, through which households and/or firms can hold (directly or through intermediaries) a liability of the central bank – a luxury hitherto reserved to banks and big financial institutions. Acknowledging that money can become a store of value regardless of the issuer's intentions, the European Central Bank has repeatedly made clear that it will not allow any single holder of CBDC to have more than 3,000€ in the form of digital euros. This constraint aims at the CBDC to be a convenient means of payment but with limited scope as a store of value for the single individual. However, as noted by Temperini et al. (2024), a maximum holding of 3,000€ per capita implies a potential issuance of CBDC of around 5% of GDP of the eurozone, which for society as a whole is not a negligible value.
An aspect not fully clear yet is how the digital euro will be issued in practice. Cesaratto and Febrero (2023) consider several possibilities with different roles for financial intermediaries, including e.g. a scenario of "narrow banking" or full disintermediation, in which banks transfer households' deposits to the central bank and receive reserves in exchange. Less radical possibilities include the possibility of buying e-tokens by exchanging them for other forms of money (e.g. banknotes; or bank money, with a partial disintermediation). We consider here two broad options in which, for simplicity, final users are assumed to directly hold units of central bank liabilities (such as a deposit with the central bank), and we refer to Cesaratto and Febrero (2023) for how a discussion of the role of intermediaries could change some risk and reward profiles of this asset. On the one hand, we consider a helicopter money policy, in which the central bank simply creates new buying power and attributes it to firms or households (it opens new deposits in their name); and on the other hand, an issuance based on the exchange of CBDC for the corresponding value of some other financial asset, which end up in the central bank's balance sheet and is thus subtracted from circulation.

2. Modelling the eurozone economy

We use the SFC model proposed by Temperini et al. (2024), which largely builds on the work of Sawyer and Passarella (2021) (henceforth SP). We devised a set of parameters (reported in appendix C) with two criteria. In general, they follow SP (2021), or are obtained from the literature, and they overall are determined in a way that makes our baseline scenario comparable to the long-term development of the eurozone economy over the period 1999-2019. For the parameters that define the transmission channels of the various policy shocks, we referred to the empirical literature applied to Europe, whenever possible, or to other developed economies when necessary. With a conservative approach, faced with a range of values with referred to the upper bound for the less effective scenarios in our model (e.g., QE) and to the lower bound for the more effective (e.g., CBDC).
The model is composed of seven sectors: lower-class households, upper-class households, non-financial firms, the commercial banking sector, the central bank, the government, and the rest of the world. The transactions and balance sheets matrices are reported in appendix A tables 1 and 2. By distinguishing between two classes of household, the model envisages

a group of households who only earn income from labour, the lower-income class, and one (the upper-income class) composed of households who earn both labour income and capital incomes. The latters take two forms in model: distributed profits from productive firms; and financial rents, encompassing: returns on savings deposits, returns on government securities, and bank profits (we classify the latter among the financial rents because in the model they are exclusively derived from markup pricing on loans and therefore they can hardly be called profits, following Mazzuccato et al., 2023; Carletti et al., 2024).

In the model, the central bank sets interest rates and meets the demand for money in each period. The central bank buys all government bonds not purchased by other sectors and provides the banking sector with all required reserves. We slightly modified SP's original model concerning the way the central bank implements QE.[5] For this scenario, we assume that the central bank exogenously increases its demand for government bonds and obtains them from (upper-class) households. This implies that in the financial markets there is an additional demand for government bonds which could affect their price (an aspect not explicitly modelled in SP). In turn, the change in bond prices could induce households to change their portfolio allocation according to the Tobinesque choice model (which is already in SP).

Moreover, explicitly accounting for market prices of stocks and government bonds allows us to introduce capital gains for the upper-class households, holders of such securities. In a stock-flow consistent model, that is, when considering the household sector as a whole, unrealized capital gains should not be considered as part of income and wealth for the sector, until the assets are sold to some other sector and the gains are realized. However, we assume here that households have a "microeconomic" perspective and thus suffer from a sort of monetary illusion by considering themselves immediately richer as the market price of assets grows (this assumption is functional boosting the real impact of QE in our simulations, which otherwise would be extremely small, and which nonetheless remains rather small, as will be seen). However, because of the unrealized nature of these gains, we do not include them in the definition of income, which is crucial to our aims when measuring income inequality.

A second change with respect to the original SP model concerns the consumption functions of the two classes of households. Already in SP (2021), instead of a single, average propensity to consume out of wealth, households have different propensities to consume different classes of assets. Recently, De Bonis et al. (2023) provided evidence for the Italian case, that indeed households have a larger propensity to consume more liquid assets. However, in accordance with a conservative approach, when we introduce a new asset class, the CBDC, we assume that the propensity to consume it is rather low, despite it being very liquid. Specifically, while for the euro area Skudelny (2009) estimates a marginal propensity to consume out of financial wealth between 2.4% and 3.6%, we use a value that is well below the lower bound, setting our parameter at 1.6%.[6]

A third change with respect to the original model concerns the relative sizes of the two classes of households. While this aspect is not modelled by SP, we formalize the share of high-income households in the population to obtain measures of per-capita incomes of the two classes. Following Piketty (2014), we assume that if the difference between the growth rate of GDP (g) and that of capital incomes (r) is positive, we could expect less concentration

[5] This is not a trivial point in the model, as already in the baseline scenario the central bank supplies all money that is demanded.

[6] Temperini et al. (2024) show that the helicopter money scenario based on the issuance of CBDC to households remains the most effective one in terms of GDP growth, among those they consider, for all plausible values of the propensity to consume the CBDC.

of wealth or, in other words, the share of high-income households increases given the same level of wealth for this class of households.
Finally, the last innovation in our model concerns an explicit relationship between the investments that firms choose to undertake and the interest rate. Although such elasticity is criticized both on theoretical and empirical grounds, we introduce it in order to improve as much as possible the GDP impact of those scenarios that appear to be least effective (again, to no avail, in the sense that the Pasinetti Rule in particular remains the least effective policy shock in terms of GDP growth – see below). We refer to the Tori and Onaran (2020) for an estimate of the main elasticities of investments in Europe, with respect to: firms' financial leverage: they estimate a coefficient (for the investment to assets ratio) between -0.016 and -0.031, and we use -0.8, significantly outside of the confidence interval; Tobin's Q: they estimate a coefficient between 0.113 and 0.182, and we use 0.4 (again, significantly outside of the range); and the interest rate: they estimate a coefficient between -0.049 and -1.55, and we use -0.6 (within the estimated range, but as mentioned, this is a theoretical innovation too, and a disputable one from a Post-Keynesian perspective, which we are only introducing for the sake of the argument – all the main results below would hold a fortiori, without it).

2.1. The ECB's monetary policy (2000-2019) and our policy scenarios

We compare alternative unconventional monetary policies vis-à-vis a model calibrated on the eurozone's economy during the two decades from the introduction of the euro to the pandemic crisis. Prudentially, the meaning of our scenarios is of theoretical counterfactuals, asking what would have happened to this economy, had the ECB behaved differently. Depending on one's opinion on the future of the eurozone – notably if the tendency to secular stagnation will soon reemerge, or if instead the post-crisis boom will continue – the scenarios might be indicative of present-day trends too.
Preliminary, a short summary of what the ECB actually did seems in order. In the first few years of operation, the ECB interpreted the mandate set out by the Treaty on the Functioning of the European Union,[7] as narrowly focusing on price stability. It set a quantitative target for the inflation rate, which was to be achieved by setting an interest rate corridor with the aim of controlling the growth rate of monetary aggregates. The approach was markedly monetarist (in 2023 the ECB proceded with a review of its objectives and methods of operation, but that is outside the time period considered here).[8]
In the run-up to the Great Financial Crisis (GFC), inflation rose slightly above 2 percent. The ECB's reaction was immediate and led to a series of rate increases on the marginal lending facility, from 3% in June 2003 to 5.25% in July 2008, and from 2% to 4.25% for the main refinancing operations.[9] Initially interest rates remained high even after the financial crisis erupted, and only after the Lehman Brothers bankruptcy they were gradually lowered. Toward the end of 2009 they reached 1%. At this juncture even mainstream economists criticised the ECB for having lowered rates too late and having aggravated the crisis (e.g. Lane, 2012). Faced with the zero lower bound (which it later crossed, keeping some policy rates negative for several months) the ECB lengthened the maturities of loans to the banking system, guaranteed fixed-rate liquidity requests, widened the range of collateral eligible for

[7] Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A12016E127
[8] As noted by Constâncio (2018), for some years vice-president of the ECB, the policy of setting a growth rate for M3 was not effective and the target was totally missed.
[9] Interest rate data available at : https://www.ecb.europa.eu/stats/policy_and_exchange_rates/key_ecb_interest_rates/html/index.en.html).

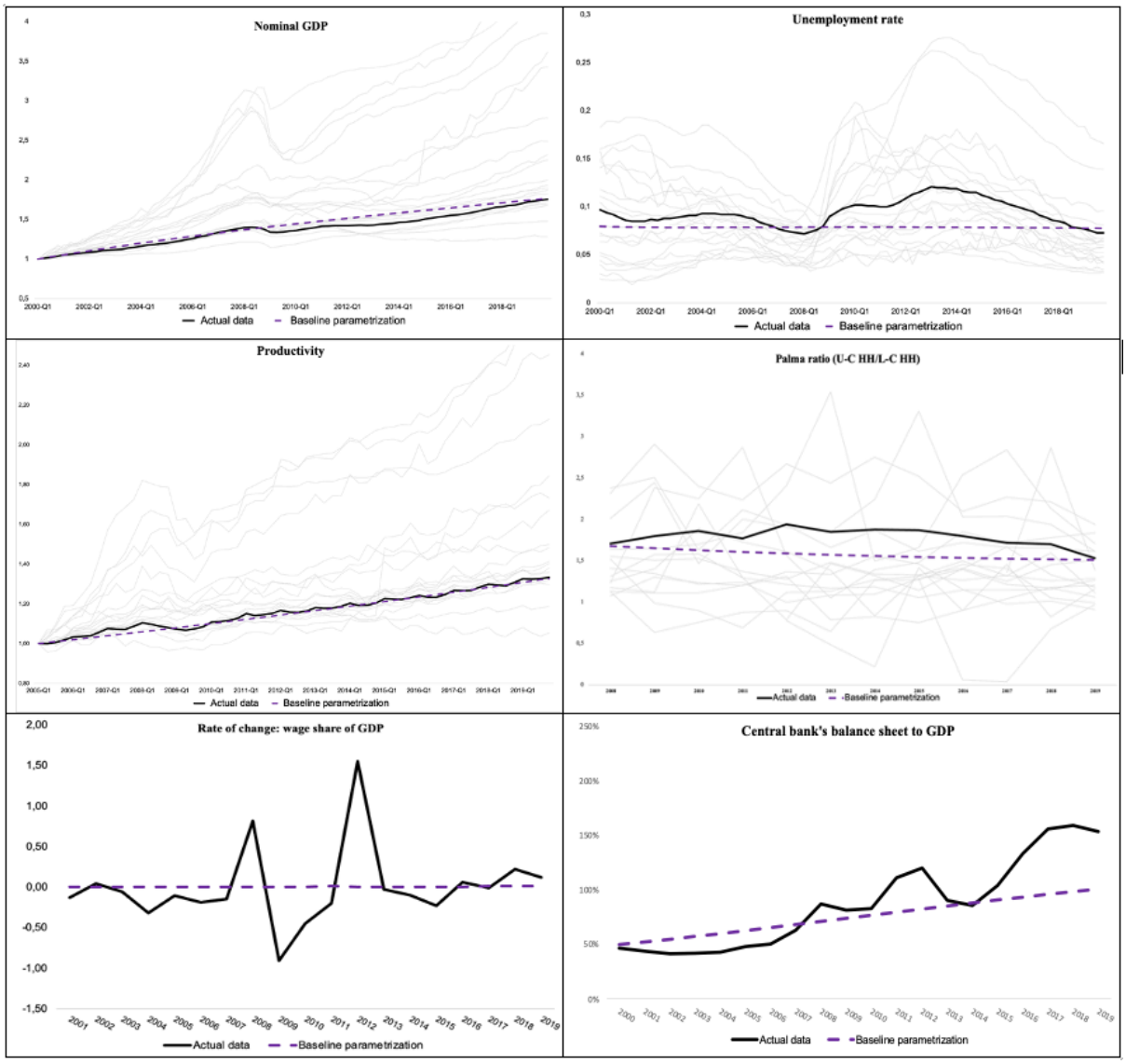
refinancing operations, and started large-scale purchases of euro-denominated bonds.
A crucial peculiarity of the eurozone, of course, is the fact that different countries share the same currency. This emerged most clearly when, after 2010, a trend of slow divergence between a stagnating “periphery” and a more solid “core” suddenly was accelerated by the sovereign debt crisis. In 2010 a newly elected Greek government announced a major revision in the official estimate of the public debt, triggering a capital flight from “GIPSI” countries (Greece, Ireland, Portugal, Spain, Italy – and actually at least Cyprus too) to the "Northern” countries (mainly Germany, the Netherlands, Austria, and France). When talk of a possible euro break up became public, the ECB finally intervened with the famous promise by Mario Draghi to do “whatever it takes” to save the euro. This implied a renewed series of “unconventional” policies - including asset purchase programmes targeted at the bonds of single countries within the eurozone, aimed at keeping interest rate spreads within a certain range - and even lower interest rates (de Guindos, 2019).
From the sovereign debt crisis to 2019, the eurozone entered a long period of stagnation. Despite two periods of deflation in the Euro Area (December 2014-March 2015, and February-May 2016), economic agents’ expectations about the central bank's ability to achieve its medium-term objective of an inflation rate “below but close to 2%” did not dissipate (Fracasso and Probo, 2017; Gobbi et al., 2019). When covid hit the eurozone, the ECB was probably already scraping the bottom of the barrel of its toolbox, and a stronger fiscal policy reaction became inevitable.

2.2. Baseline parametrization

Given the significant number of shocks experienced by the Eurozone during the period 1999-2019 (the global financial crisis, the sovereign debt crisis, the first stage of harder austerity, a second stage of softer austerity, and at the same time, a first period of restrictive monetary policy, then the “whatever it takes”, etc.), our baseline scenario has been constructed to replicate and obtain long-run trends close to those of the eurozone, and we do not intend to replicate the ebbs and flows of the shorter-term dynamics.
The basic unit of time in our model is a quarter, and we report simulations over 80 periods, to reflect a 20-years horizon. In all scenarios, we simulated 130 periods: except for the baseline, in all other cases we exposed the system to a shock at the eightieth period, and observed the behavior of the main economic variables in the subsequent periods. In the graphs presented in the results section, we depict 40 periods before and 40 periods after the shock, to illustrate the system's trend and the impact of the shock over a shorter and a longer term.
In figure 1 we show our baseline scenario (dashed purple line) against the eurozone trend (black line) and, for context, the single eurozone countries’ series (these can diverge significantly from the eurozone trend, because the latter is obtained as a weighted average, where smaller economies often exhibit a very tiny weight). As shown in the figure, our baseline parametrization matches the long-term dynamics in terms of nominal GDP, unemployment rate, and average labour productivity; concerning inequality, we replicate the long-term trends of the Palma ratio, defined here as the per-capita income of the upper class over the per-capita income of the lower class, and in terms of the labour share of GDP (represented in the figure in terms of rates of change, because the variable did not change

significantly over the period).[10]
Finally, in terms of monetary policy, we are faced with the impossibility of replicating an erratic policy (first restrictive, then expansionary, then stagnationist) and with the aim of keeping the baseline scenario as simple as possible, thus facilitating the interpretation of the various shocks in the single policy scenarios, all of which concern monetary policy shocks. We thus calibrate the baseline resulting in an overall expansion of the central bank's balance sheet broadly in line with the balance sheet of the eurosystem (the sum of the balance sheets of the ECB and of the single eurozone countries' central banks) over most of the period considered; and we hold the central bank's reference interest rate fixed, at a value equal to the average value of the ECB's marginal lending facility rate over the period considered.

Figure 1: Long-term trends in the eurozone and our baseline parametrization



[10] Clearly, depending on the specific graph under consideration, one may encounter trajectories significantly divergent from those produced by our parameterization, for some single countries; however, these dynamics affect economies with relatively low weight respect to the others.

2.3. Treatments description

We compare the baseline with six different scenarios. Each scenario is characterized by a shock worth 5% of GDP (of the immediately preceding period), except for the Pasinetti Rule scenario, in which the shock is defined on the rate of interest and not on some monetary aggregate. Obviously, 5% of GDP may appear as an unrealistic value for some of the shocks (notably for QE) but using the same value across scenarios facilitates the comparability of results. All scenarios imply changes in monetary policy: the first three are implemented without changes (at least immediately) in the total value of the central bank's balance sheet; the next three instead imply some form of helicopter money. The goal of this analysis is to compare the predictable impact of a radical innovation such as the issuance of a digital euro, with some similarly unconventional monetary policies.

As mentioned, the *first scenario* we implemented involves the central bank applying the Pasinetti Rule to determine its reference interest rate (r^*). To keep the scenario simple, such rule is followed every quarter, mechanically, and with no a priori floors or ceilings or other considerations. Simply put, from period 80th onwards, the central bank sets the interest rate by equalizing it with productivity growth plus the rate of inflation.

The *second scenario* involves the banking sector adjusting its allocation of end-of-period vailable cash – implicitly, thanks to changes in prudential regulation and/or moral suasion from the central bank. Specifically, whereas in the baseline scenario banks devote a certain amount of cash to voluntary reserves with the central bank, over and above the legal minimum, in this scenario banks shift cash for a value equal to 5% of GDP towards holding additional government securities.

The *third scenario* entails the central bank issuing a CBDC targeted to households (both the high- and low-income classes) for a value of 5% of GDP ($CBDC_s$). High-income households obtain this asset by exchanging it with the central bank for government securities, whereas low-income households for cash. The allocation of digital currency to upper-class ($CBDC_u$) and lower-class households ($CBDC_l$) is proportional to their share of the total household sector income. Since these exchanges take place at par, the issuance of CBDC is fully sterilized ($CBDC_u + CBDC_l = CBDC_s$) and the value of the central bank's balance sheet does not change, as shown in figure 2. The choice of which assets to exchange for the CBDC is aimed at deliberatively avoiding a direct impact on the banking sector (as would happen if instead households exchanged the CBDC for bank deposits or saving deposits). This way, we set out to show that there can be an (indirect) impact on the banking sector (and on distribution) even under the most radical assumption of absolutely no substitutability between CBDC and bank deposits.

The next three scenarios involve helicopter money, in the sense that the central bank's balance sheet is immediately enlarged by virtue of the very policy decision. In particular, the fourth scenario involves the issuance of CBDC to households (in the same proportions as the third one), but this is realized by means of an outright transfer from the central bank to households. For simplicity, in figure 2 we report the case that such transfer takes the form of an open-ended interest-free loan from the central bank.[11]

In the fifth scenario, we simulate the issuance of CBDC, this time targeted to productive firms (non-financial corporations). To differentiate it further from the previous ones, in this scenario we assume that firms immediately use the CBDC to reduce their outstanding debt toward

[11] The same results would hold if the transfer took place in the form of a grant from the central bank. However, this would be inscribed in the balance sheet of the central bank as a loss (reducing its equity) and therefore we consider it as less realistic due to political concerns.

the banking sector. For the banking sector, CBDC is qualitatively equivalent to voluntary reserves (in both cases it is an interest-free direct liability of the central bank), so when they receive it as a payment from the firms, they are indifferent between holding CBDC or reserves. As is the case of the previous one, this scenario is meant to show potential risks or downsides of a CBDC for the banking sector, different from those currently widely debated (that is, the obvious funding risk in case of a reduction of the household demand for deposits, as seen in section 1.2). In this case, the risk comes from a reduction of their assets side (a reduction in loans) and we choose to highlight it in the case of firms because the household sector in Europe is a net creditor to the rest of the economy.

Finally, in the sixth scenario, we simulate a more conventional "unconventional" monetary policy, i.e. quantitative easing. Here the central bank does not passively demand whatever government securities are needed to reach its interest rate target, as in the baseline scenario, but rather it autonomously decides to increase its holding of such securities with respect to the baseline, by an amount equal to 5% of GDP. These additional securities are bought on secondary markets from the upper-class households, prompting them to adjust their wealth allocation toward other assets: partially bank deposits, and partially stocks. As mentioned, differently from PS (2021) we model these portfolio changes as caused by, and in turn originating, changes in the various asset prices and interest rates, so that asset price inflation could emerge as a consequence of the central bank's policy shift.

Figure 2: Changes in balance sheets in selected scenarios

Scenario 3:

A. Pre-shock

Upper-class households	
Assets	Liabilities
h_u	v_u
$m1_u$	
$m2_h$	
e_h	
b_h^0	

B. Post-shock

Upper-class households	
Assets	Liabilities
h_u	v_u
$m1_u$	
$m2_h$	
e_h	
$b_h^0 - CBDC_u$	
$CBDC_u$	

C. Pre-shock

Lower-class households	
Assets	Liabilities
h_l^0	l_h
$m1_l$	v_l

D. Post-shock

Lower-class households	
Assets	Liabilities
$h_l^0 - CBDC_l$	l_h
$m1_l$	v_l
$CBDC_l$	

E. Pre-shock

Central bank	
Assets	Liabilities
a_s	h_s^o
h_f	hb_s
b_{cb}^0	hb_s^*

F. Post-shock

Central bank	
Assets	Liabilities
a_s	$h_s^o - CBDC_l$
h_f	hb_s
$b_{cb}^0 + CBDC_u$	hb_s^*
	$CBDC_s$

Scenario 4:

A. Pre-shock

Upper-class households	
Assets	Liabilities
h_u	v_u
$m1_u$	
$m2_h$	
e_h	
b_h	

B. Post-shock

Upper-class households	
Assets	Liabilities
h_u	l_{CBDCu}
$m1_u$	v_u
$m2_h$	
e_h	
b_h	
$CBDC_u$	

C. Pre-shock

Lower-class households	
Assets	Liabilities
h_l	l_h
$m1_l$	v_l

D. Post-shock

Lower-class households	
Assets	Liabilities
h_l	l_h
$m1_l$	l_{CBDCl}
$CBDC_l$	v_l

E. Pre-shock

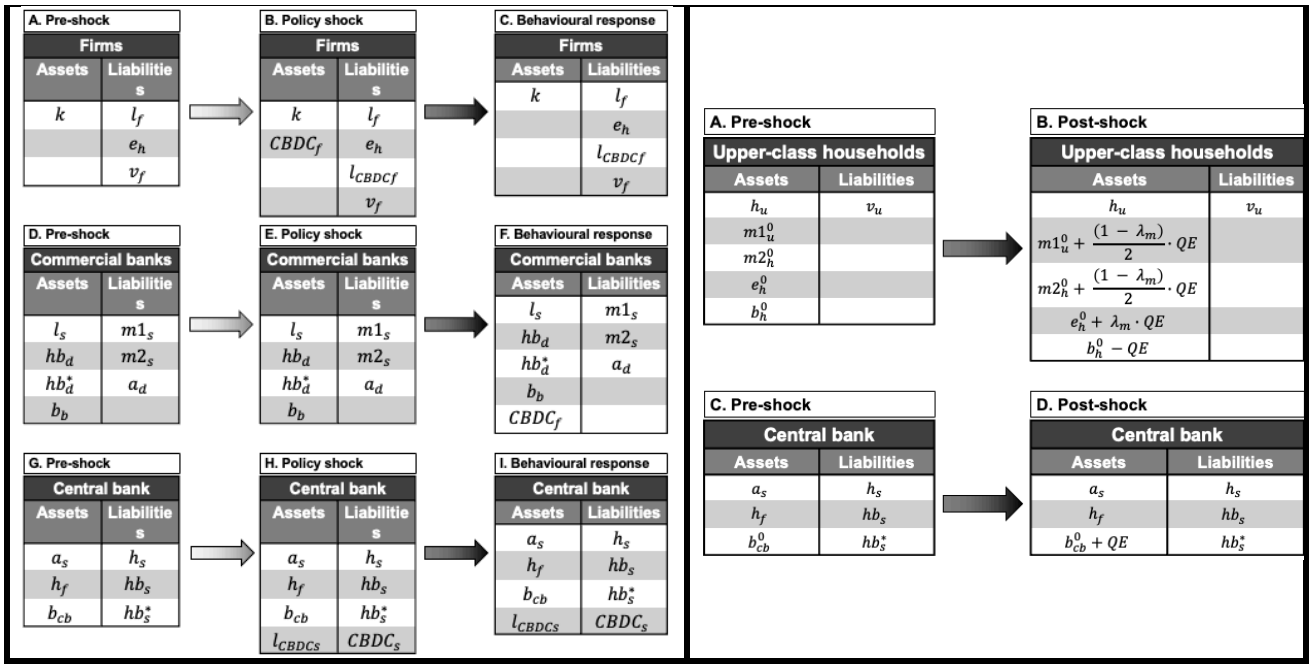
Central bank	
Assets	Liabilities
a_s	h_s
h_f	hb_s
b_{cb}	hb_s^*

F. Post-shock

Central bank	
Assets	Liabilities
a_s	h_s
h_f	hb_s
b_{cb}	hb_s^*
l_{CBDCs}	$CBDC_s$

Scenario 5

Scenario 6



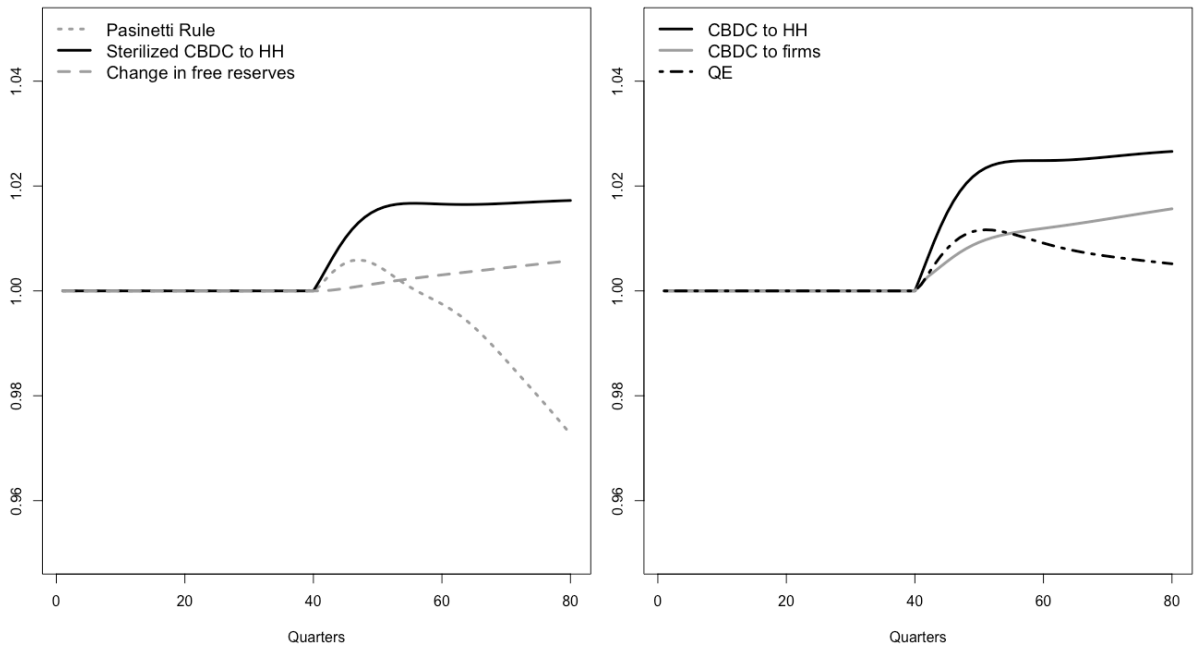
3. Main findings

3.1. Economic activity

To correctly interpret the impact of monetary policy on functional and personal income inequality, it is necessary to consider both direct and indirect effects. Therefore, preliminarily we summarize here the six scenarios' main results in terms of GDP growth, unemployment and inflation.

Regarding GDP (Figure 3), it can be observed that the policies that do not imply an exogenous expansion of the monetary base tendentially induce a smaller boost to economic growth than helicopter money policies, but with wide differences across scenarios. Among scenarios 1 to 3, that based on the sterilized issuance of CBDC to households has the highest impact on GDP, both in the short and the long run. GDP growth is driven here by increased consumption (as shown in Figure 4.a) and is then supported in subsequent periods by some induced investment growth (Figure 4.b). The main transmission mechanism is households' propensity to consume liquid wealth (on which, see section 2).

Figure 3: GDP in the different scenarios, on baseline



The second scenario too, with the increase in the demand for government securities from commercial banks, has a mildly positive effect on GDP, cumulatively less than 1% over the period. By contrast, implementation of the Pasinetti rule[12] appears to have an immediate small positive impact on GDP, thanks to the immediate growth of investments (Figure 4.b), but it soon leads to a less dynamic path than the baseline in the medium-long term, due to the decrease in consumption (Figure 4.a). The decline in consumption in this scenario is attributable to the decrease in financial incomes, on which we comment below, and consequently the lower growth over time of the wealth of higher-income households. Despite our very favourable choice of parameters (discussed above) such a decline in consumption more than offsets investment growth. As a consequence GDP growth is still positive, but lower than what has actually been observed in the eurozone over 2000-2019: our simulation imply that, had the central bank followed consistently this policy, at the end of the period GDP would have been 3% smaller.

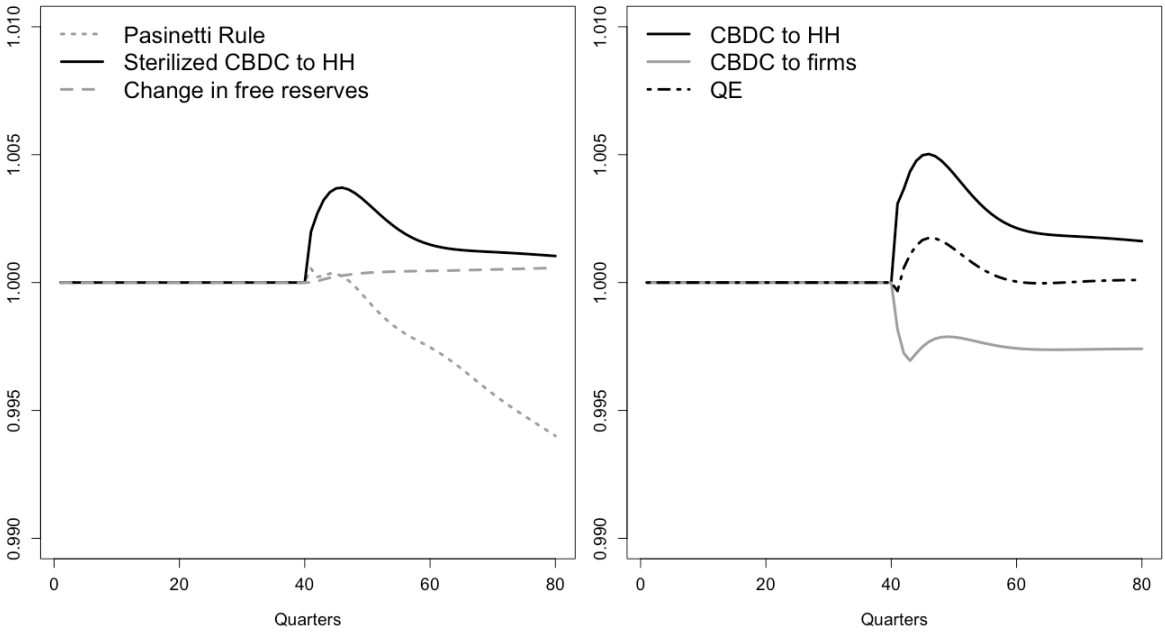
As mentioned, scenarios 4 to 6 tend to exhibit a larger GDP boost. The scenario in which CBDC is credited to households through an expansion of the monetary base has the greatest impact in both the short and long run (Figure 3). This growth arises from the large increase in consumption due to increased household wealth, which in this scenario is not even partially offset by the decrease in other assets. Here too, induced investment then fuels further expansion.

In both cases – sterilized issuance of CBDC and helicopter money – it appears that an effective way to sustainably increase investments in the eurozone is by inducing a reliably high and stable consumption growth. Due to its hybrid fiscal-monetary nature it seems that, paraphrasing Minsky ([1982], 2016), a CBDC has the potential to allow at the same time the effects of a Big Bank and a Big Government. This makes it potentially a very helpful tool for example during financial crises.

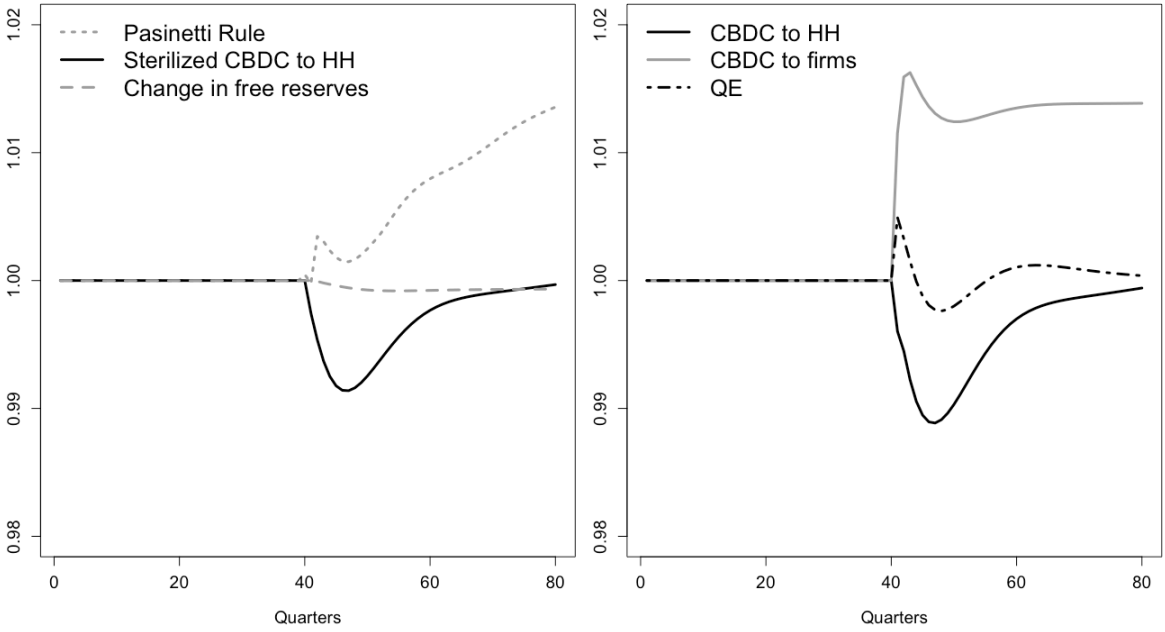
[12] In the appendix (E1), we have developed a sensitivity analysis with respect to different specifications of the Pasinetti rule.

Figure 4: The real market

Panel a. Consumption on GDP, scenarios on baseline



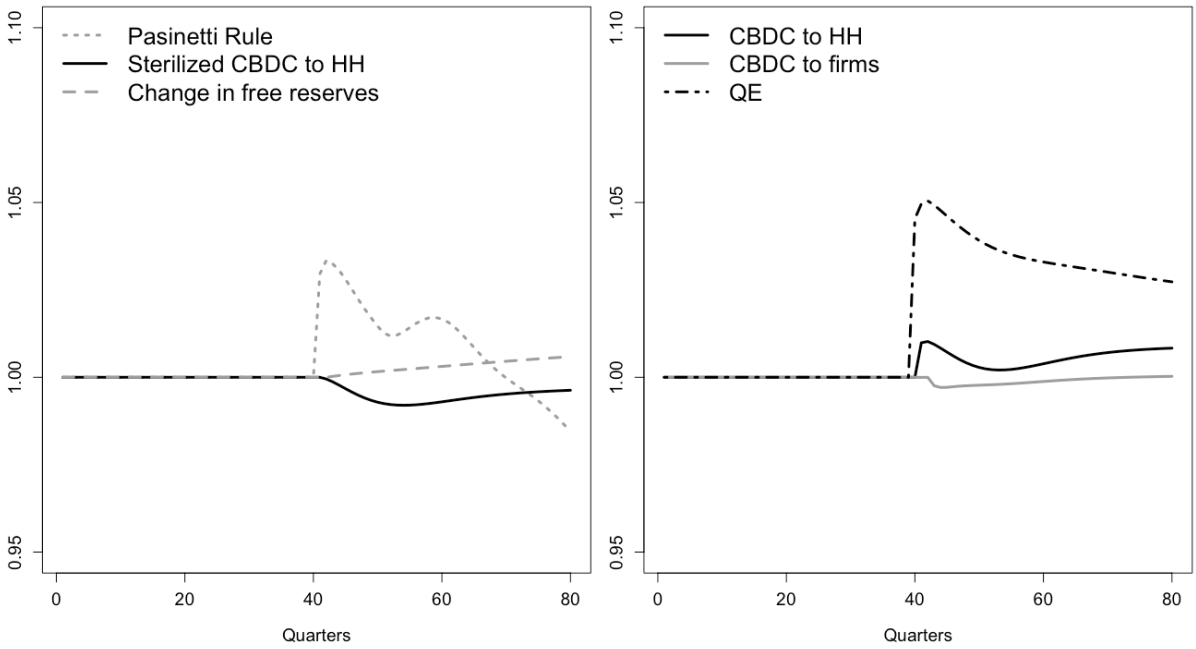
Panel b. Investments on GDP, scenarios on baseline



A different dynamic is triggered in the scenario where the CBDC is credited to firms, under the assumption that firms use it to deleverage. In this scenario there is an increase in investments on GDP due to the elasticity of investment to firms' leverage (since the CBDC is an irredeemable loan, we assume it does not enter into firms' leverage), firms' reduced interest expenditure due to lower debt, and a slight reduction in the interest rate on banks' loans due to the lower demand for credit and the lower riskiness implied in the firms' lower leverage. Since investments only constitute a low fraction of GDP (and since they are not very reactive anyway), initially the boost to GDP is rather low (Figure 3). However, contrary to what happens with the Pasinetti Rule (where the interest rate is adjusted at every quarter to reflect the dynamics of inflation and productivity), in this scenario the central bank does

not change the direction of policy – namely, it does not ask for the CBDC back. Consequently, over time the higher investments slowly produce a growth rate that, in the long run, is the second highest among our scenarios, with a GDP at the end of the period slightly less than 2% above the baseline.
Finally, the implementation of QE (or rather of additional QE with respect to the baseline) has an initial positive effect on GDP (Figure 3) due to a short-term growth both in consumption (Figure 4.a) and in investments (Figure 4.b). This positive effect largely follows from our innovation with respect to SP (2021) in the form of a reaction of asset prices to the increased demand from the central bank (Figure 5). On the one hand, higher prices imply lower interest rates, which induces some additional investment. On the other hand, higher prices constitute unrealized capital gains that will to some extent stimulate the consumption of higher-income households. However, both the stimulus to consumption and to investments fade over time, and despite our attempt at making the most favourable assumptions possibly for the QE scenario, over the long term we do not find a significant impact on GDP, with a GDP level at the end of the simulation period not even 1% higher than in the baseline. For this reason, it seems reiterate that properly speaking, asset price inflation produces here *unrealized* capital gains, due to monetary illusion. In real terms, upper-income households' financial wealth is actually eroded over time due to their higher consumption.

Figure 5: Equity prices, scenarios on baseline



Concerning macroeconomic indicators beside GDP, the unemployment rate and the price level are especially important in connection to monetary policy. Regarding the inflation rate, we find that five simulated scenarios show a long-term inflation dynamic not different from that of the baseline scenario. Although there is a modest increase in inflation in the short run, all five scenarios subsequently readjust to the baseline level (Figure A1 in the Appendix). In the Pasinetti Rule scenario, this readjustment is quicker because by our definition of the Rule, after the initial growth in GDP, and therefore in the inflation rate, the central bank immediately reacts by raising the interest rate. In the medium to long run, inflation is lower

in this scenario than in the baseline, mostly due to the slower GDP growth.
The opposite happens to the unemployment rate (Figure A2 in the Appendix): all scenarios imply an immediate reduction that is then reabsorbed either partly (in the CBDC scenarios) or almost fully (in the QE scenario), except for the scenario on the change in the allocation of banks' free cash, where the unemployment rate exhibits a slow but steady decrease with respect to the baseline, reflecting the slow increase in GDP and consumption. Incidentally, our simulations for the QE scenario – the only policy that has been implemented so far – with first a reduction and then no discernible effect, is consistent with the evidence for the eurozone (Beck et al., 2019). Again, the Pasinetti Rule scenario depicts a different picture than the other scenarios, with an unemployment rate in the medium and long run higher than in the baseline scenario – as is expected with lower GDP growth.

3.2. Income distribution and inequality

In our model, low-income households receive wages from firms, and they hold cash, possibly CBDC, and deposits, while high-income households receive financial incomes too and, in addition to the assets mentioned, hold savings deposits, government bonds, and stocks issued by firms. To gauge the impact of the six policy shocks on income inequality, we consider functional inequality, in terms of the shares of wages, profits, and financial returns to GDP; and personal income inequality, in terms of the ratio of upper-income households' per capita income to lower-income households' (Palma ratio).
Concerning functional distribution, a general finding is that the wage share is not significantly affected in any policy shock (Figure 6), and all impacts are limited to changes in the shares of rents (Figure 7) and profits (Figure 8) on GDP. Especially for the figures presented in this section, we would like to point out that the values represented in the vertical axis are different for each graph. This choice allows us to observe in greater detail the different dynamics between scenarios, even if they do not differ much from a quantitative point of view. Recalling the substantial stability of the wage share in the period covered by our baseline scenario, this result is consistent with the empirical evidence that small changes in the unemployment rate are not sufficient to ignite a significant wage growth (the "death of the Phillips curve") and that possibly other kinds of policies, such as structural reforms, may be more effective in increasing or decreasing workers' relative bargaining power.
According to our simulations, expansionary monetary policies tend to depress rents and increase profits, but this impact is visible for the Pasinetti Rule and the issuance of CBDC, and negligible (or even slightly opposite) for QE or the change in banks' cash allocation.

Figure 6: Wages in GDP, scenarios on baseline

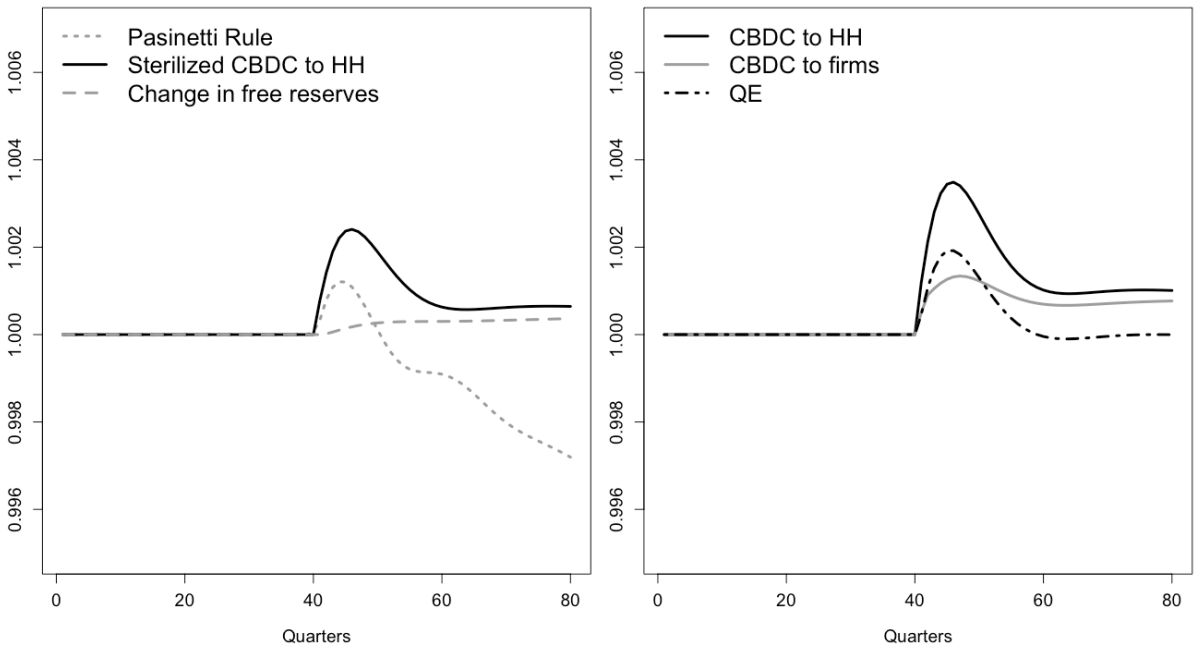


Figure 7: Financial rents in GDP, scenarios on baseline

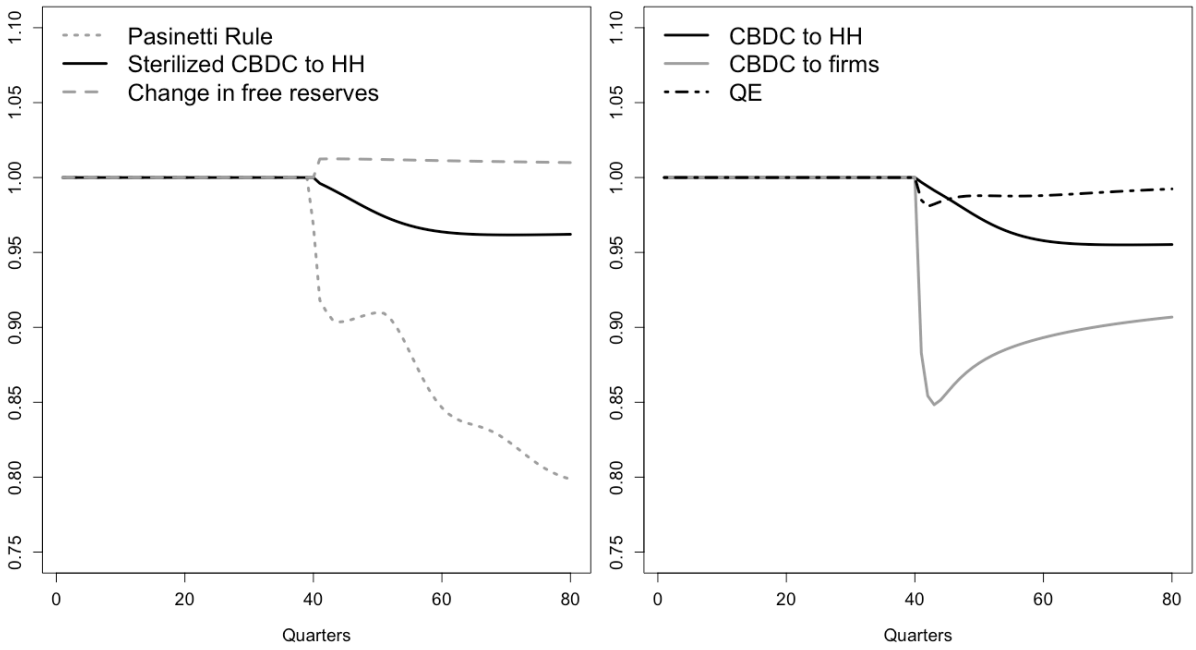
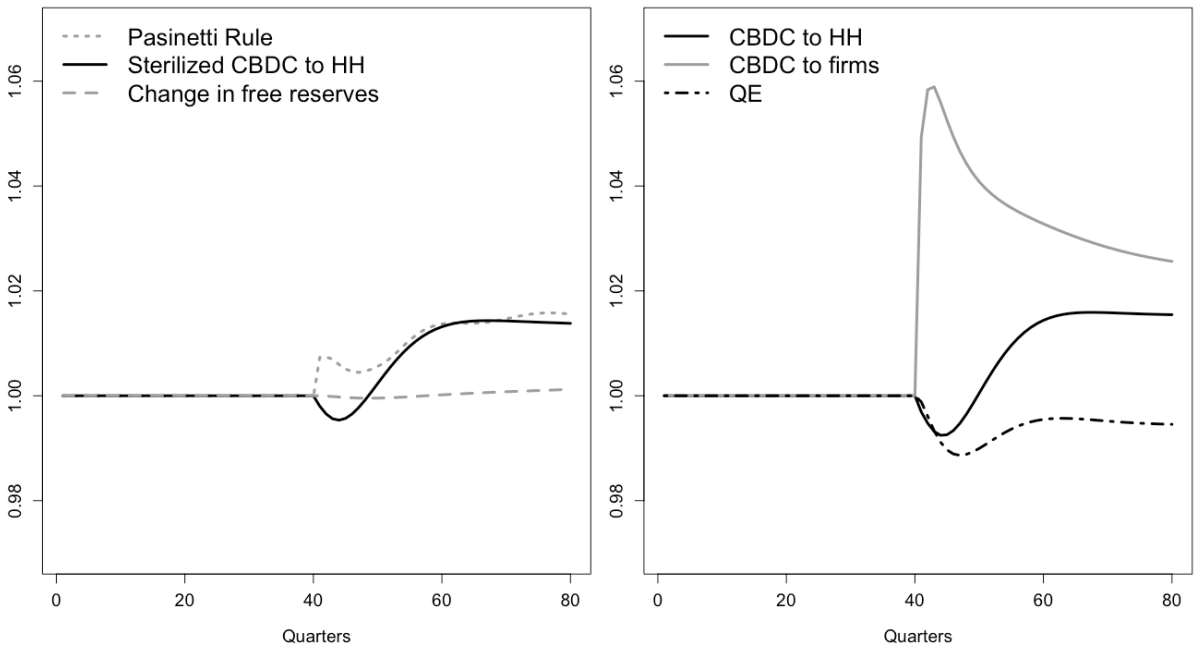


Figure 8: Gross operating surplus to GDP, scenarios on baseline



Concerning personal incomes, we preliminarily report per-capita real wages in Figure 9. Although not strictly a measure of inequality, this proxy of individual wellbeing shows that, despite the wage share being stable, workers' purchasing power does differ significantly across the scenarios. Specifically, it follows a trend not too dissimilar from GDP growth, implying that in our scenarios the benefits of growth are roughly equally shared between labour and capital incomes. Clearly, this outcome (broadly reflective of the 2000-2019 trend) should be interpreted in light of the significantly lower wage share that prevailed in the European economy with respect to the previous decades. In other words, the significant redistribution of income away from the labour share had already taken place before the decades considered here.

Finally, in Figure 10 we report the Palma ratio of upper-income households' incomes over the lower-income households'. In most cases, we find relatively positive immediate impacts of monetary policy that tend to fade over time. Two significant exceptions are the scenario with issuance of CBDC to firms, and especially the Pasinetti Rule. In the former case, after an initial bounce back, we find a long-term trend toward decreasing personal inequality. This happens as a consequence of the investment-driven growth that sets in after the initial shock to the economy, which is genuinely profit-led. In contrast, the consumption-driven growth in the CBDC to households scenario is not really wage-led (in the sense that in the medium term, the real wage stabilizes at a higher value than the baseline, but with little further long-term growth) but rather due to wealth effects. Therefore, in the CBDC to firms scenario the reduction in personal income inequality is implied by the lower baking profits that get translated into lower financial rents for the upper-class households. In contrast, the CBDC to households there is even a small asset price inflation (due to higher demand for other assets when households see their wealth increase, to rebalance their portfolios) which runs counter to the decrease in inequality.

The other notable trend concerns the Pasinetti Rule scenario. Although, as seen in figure 9, the real wage tends first to increase and then to decrease in this scenario, owing to lower overall economic activity, personal income inequality decreases both immediately and in the longer term. This is due to the substantial reduction in financial rents, which overall imply a convergence to the bottom between the incomes of upper income and lower income

households.
Finally, concerning the two last scenarios, we confirm that the any impact of QE is temporary and inequality (and the real wage, and GDP shares) tends to converge back to the baseline over the long term. In contrast, the different allocation of cash by the banking sector, away from reserves and toward government securities, has the tiniest but also permanent effect, of slightly increasing real wages but also financial rents, with a final negative impact on (an increase in) personal income inequality. This is due to the rise in price in government bonds, as well as the higher interest payment that the banking sector receives from the government (which in the baseline is paid to the central bank, which returns it back to the government in the form of seigniorage profits). Quantitatively, this impact is not remotely comparable to those of the CBDC to firms and Pasinetti Rule scenarios.

Figure 9: Real wages per employee, scenarios on baseline

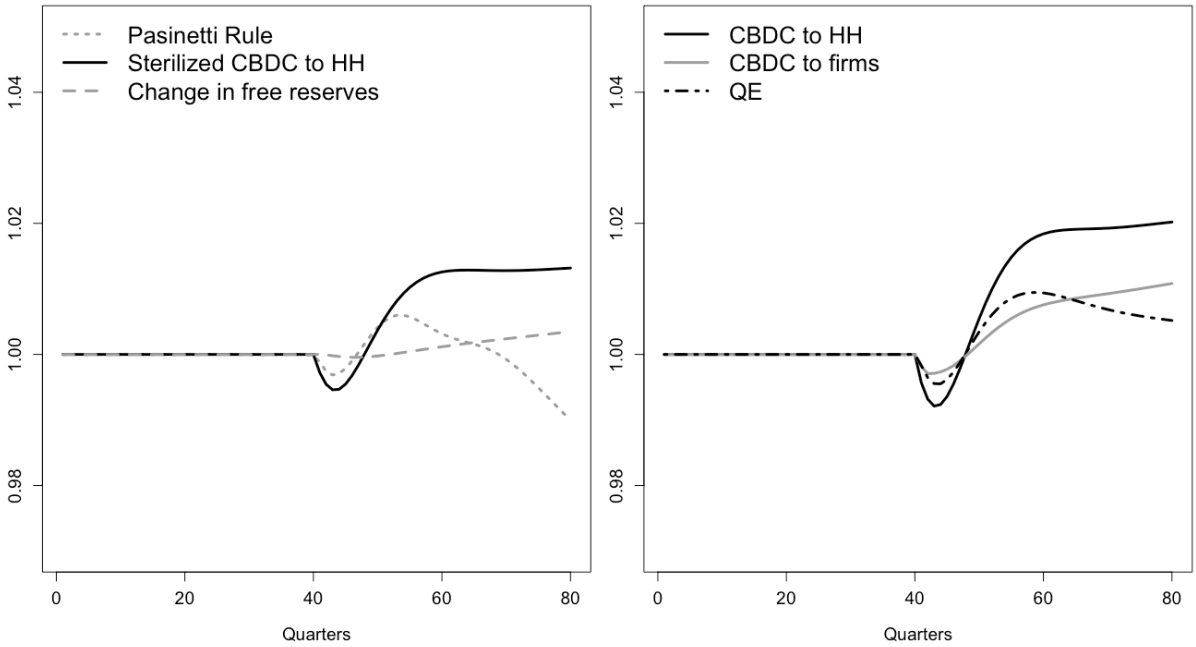
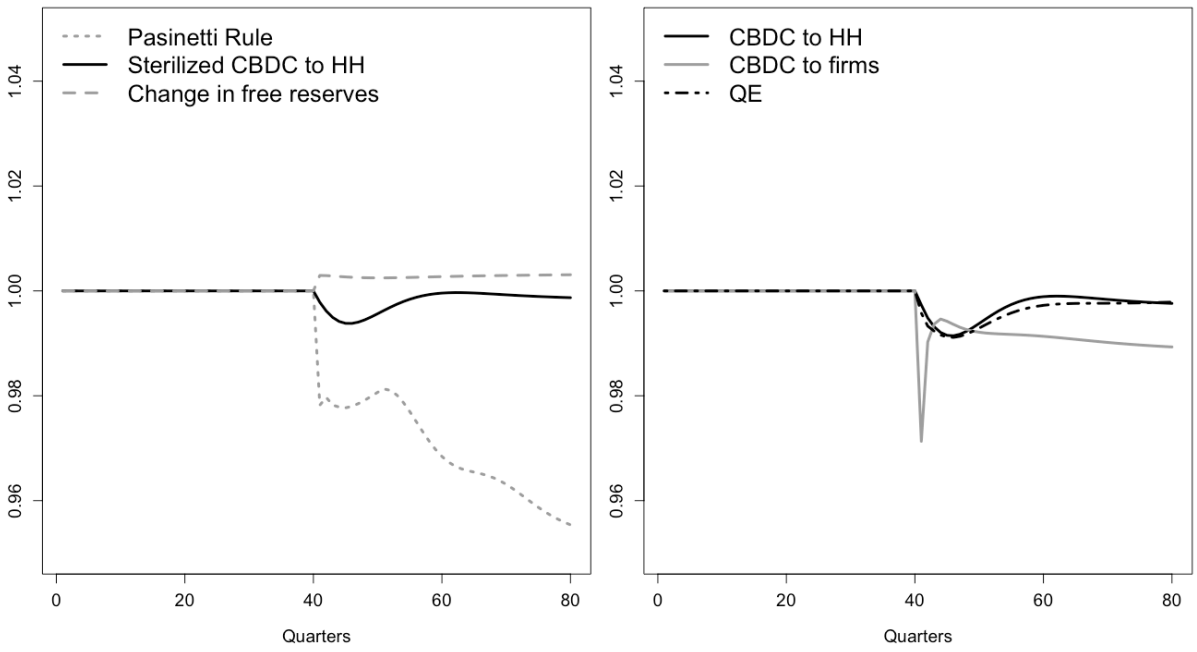


Figure 10: Ratio of the disposable income per capita of the upper-class over that of the lower-class, scenarios on baseline



Regarding the scenarios of QE and the two in which CBDC is distributed to households (with and without sterilization by the central bank), we can observe how in the long term, such policies lead to a substantial and enduring increase in the wage per worker (Figure 10), but no variation in terms of inequality in the ratio between disposable income for high and low-income households (Figure 9). Finally, the only policy that results in both an increase in the value of the wage per worker (Figure 10) and a constant reduction in the ratio between disposable income per capita of households and disposable income per capita of working households is the scenario in which the central bank distributes CBDC in favor of firms (Figure 9). As mentioned earlier, in this scenario, the mechanism triggered concerns the elasticity of investments both to the interest rate and to the firm's leverage, stimulating investments by the latter and having a subsequent impact on both unemployment and labor incomes.

4. Conclusions

Central bankers have innovated considerably their toolbox and practices over time, and plans for yet another radical innovation are well underway in the eurozone and elsewhere. Abstracting from debates on new digital technologies, we find it relevant to note that technology makes it feasible for the first time potentially for every citizen to have direct access to a central bank's liability beyond the mere coins and banknotes. Such an asset has obvious attractiveness as a store of value, so that the European Central Bank plans to only allow people to hold up to 3,000€. Yet, multiplied by the number of individuals who live in the eurozone, the figure represents around 5% of the GDP of the area, and nothing prevents the same central bank to possibly increase this ceiling, should conditions require (for example, in case of a new deep crisis).

Comparing this new instrument with other, similarly unconventional monetary policy tools, we find that it holds potential for great effectiveness in terms of GDP growth, and less clear-cut impacts on income inequality than one might expect. Across scenarios of unconventional policies, we find that distributive impacts seem to be driven by the aggregate demand and

employment impact more than by direct effects, especially in the medium to long run. Another general result of our simulations, parametrized on the eurozone economy in the past two decades, is that monetary policy seems to affect the distribution of capital incomes between firms' profits and financial rents, while very little effect is found on wages. In both cases, it is unclear how specific these results are, to the specific area and time considered here, or how instead they could generalize beyond the eurozone.

Unsurprisingly, we find that helicopter money is more effective in boosting growth than policies with no expansion of the monetary base, and in the long run, mere transfers of purchasing power seem to be less effective than changes in some basic parameters of the economy – such as the private sector financial leverage – both in terms of growth and distribution of income.

Our approach made it necessary to consider "clean" policy shocks, but for policy analysis, it could be worthwhile for central banks to investigate different policy mixes aimed at muti-objective approaches (e.g. Hwang and Masud, 2012; Chankong, V. and Haimes, Y. 2008; Gaffeo and Gobbi, 2021). For example, the Pasinetti Rule for the interest rate policy, which is found here to be very effective in taming personal income inequality, could (be applied less mechanically and) fruitfully be integrated with balance sheet policies that make sure the overall policy stance is not restrictive. In this context, it is clear from our analysis that CBDCs are candidates to become indispensable monetary policy instruments in the near future, and they definitively warrant further research beyond the current narrow debate on the possible funding risk for commercial banks.

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Appendix A:

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**

Appendix B:

Additional results

Figure B.1: Inflation rate, scenarios on baseline.

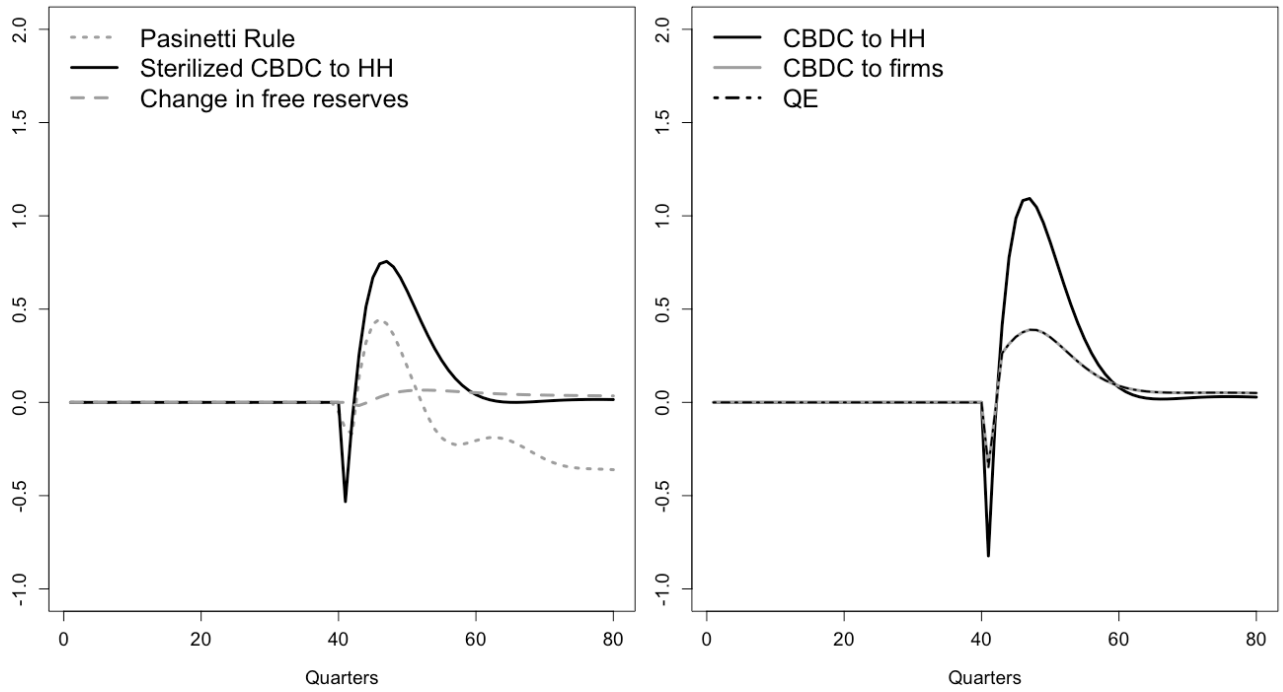
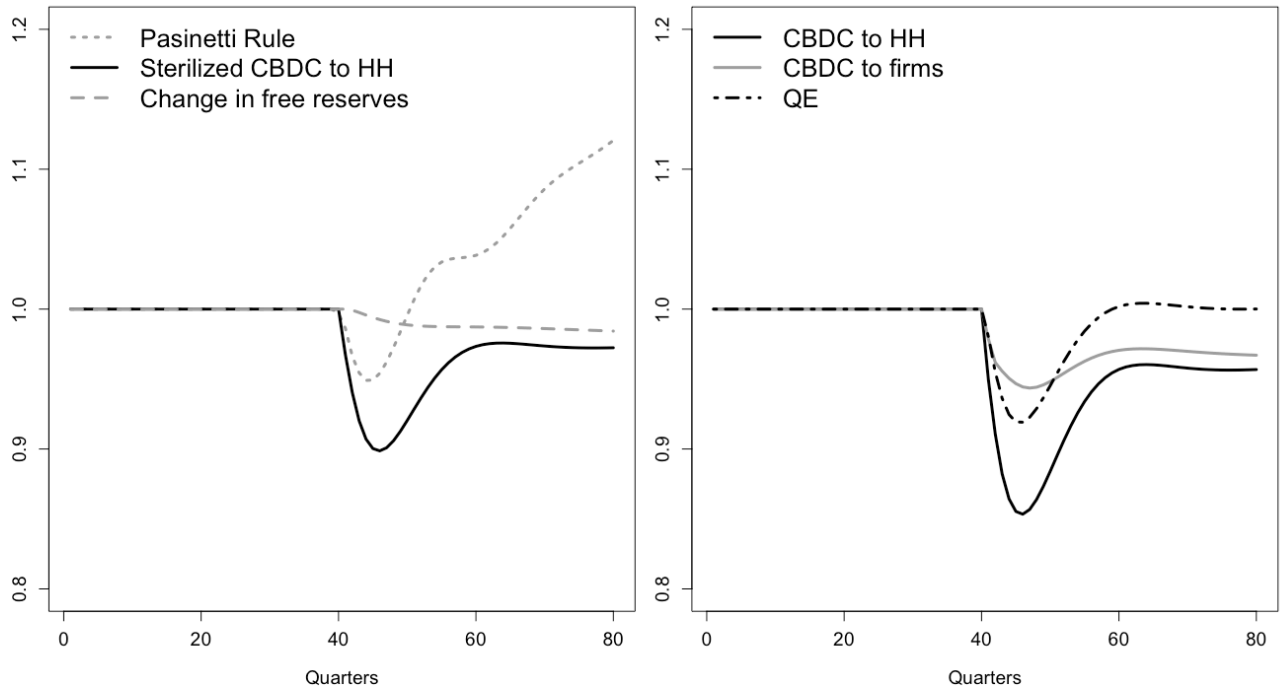


Figure B.2: Unemployment rate, scenarios on baseline


Pasinetti Rule
Sterilized CBDC to HH
Change in free reserves
CBDC to HH
CBDC to firms
QE
1.2
1.1
1.0
0.9
0.8
0
20
40
60
80
Quarters

Appendix C:

Model parameters

Symbol	Value	Parameter
α_1	0.75	Propensity to spend out of income of lower class households
α_{10}	1.5	Autonomous component of the propensity to spend of LC households
α_{11}	25	Sensitivity of the propensity to spend to the interest rate
α_{12}	0.05	Sensitivity of the propensity to spend to the unemployment rate
α_7	0.15	Propensity to spend out of income of upper class households
α_{CBDCu}	0.05	Propensity to spend the CBDC for upper class households
α_{CBDCl}	0.05	Propensity to spend the CBDC for lower class households
α_{im}	1.5	Imitative component of consumption
α_{id}	0.6	Investment elasticity to interest rate
α_{00}	0.6	Wealth effect for upper-class households
α_{m1}	0.015	Propensity to spend out of wealth: cheque deposits for households
α_{m2}	0.01	Propensity to spend out of wealth: savings deposits for households
α_{ru}	0.016	Propensity to spend out of wealth for the upper class households
α_{rl}	0.035	Propensity to spend 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	0.5	Percentage of low skilled workers to total workers
χ	0.1	Target percentage of investment to be funded by share issues
δ	0.07	Depreciation rate
γ	0.017	Reaction speed of adjustment of capital to its target value
κ_0	2	Autonomous capital-output ratio
κ_1	2	Sensitivity of capital-output ratio to Tobin's q
κ_2	-4	Sensitivity of capital-output ratio to leverage ratio
η	0	CBDC-induced investment (as a share of CBDC loan)
ξ	0.04	Mark-up over labour cost elasticity to unemployment rate

elqrs	0.3	Tobin Q elasticity to interest rate
elcgrs	-200	Capital gains' elasticity to interest rate
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	End.	Mark-up over labour cost
Ω_1	0.2	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
ψ_2	1	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	0.2	Autonomous component of government spending
σ_1	0.3425	Dependent component of government spending
τ_0	0.1	Autonomous component of tax revenue
τ_1	0.37	Tax rate on labour income
τ_2	0.3	Tax rate on capital income
τ_3	0.01	Tax revenue rate on wealth
θ	0.13	Profit retention rate
g_F	0.0043	Foreign income growth rate
g_l	0.003	Structural rate of growth of labour force
g_S	0.3	De-growth rate of income growth rate
gr_{prf}	0.0048	Growth rate of labour productivity
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	0.07	Non-inflationary rate of unemployment
pik	0.001	Piketty parameter for popolation
QE	0.05	Size of the QE program
r^*	0.006	Policy rate
rep	0	Repayment rate on personal loans
wh_0	3	Initial value of skilled workers wage rate
wh_1	0.05	Inertia coefficient of skilled workers wages
x_0	-2.1	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

Appendix D:

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	$id = \gamma \cdot (k^T - k_{-1}) \cdot p + da + \eta \cdot CBDC_{f-1} \cdot p + \alpha_{id} \cdot (1 - r_l)$	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	$cap_{soc} = cap_{soc-1} + (esr - esr_{-1}) \cdot pe$	Firms' equity
13	$esr_r = esr_{r-1} + \chi \cdot id$	Securities issued by firms
14	$esr_{n=} esr_r \cdot pe$	Securities issued by firms nominal

15	$v_f = k - l_f - bv - pass_f$	Firms' net wealth
16	$y_{pot} = ns_{pot} \cdot prf \cdot p$	Potential GDP

2.2- Households

17	$yd_l = wb \cdot (1 - \Omega_r) - r_{lh-1} \cdot l_{h-1} + tr_l - tax_l$	Disposable income of lower-class HH
18	$yd_u = wb \cdot \Omega_r + r_{m2-1} \cdot m2_h + tr_u + r_{b-1} \cdot b_h + fd_f + f_b - tax_u$	Disposable income of upper-class HH
19	$yd = yd_l + yd_u$	Total disposable income of households
20	$r_l = h_l + m1_l + att_l + CBDCs_l$	Lower-class HH's assets
21	$r_u = h_u + m1_u + m2_h + b_h + e_h + att_u + CBDC_{su}$	Upper-class HH's assets
22	$c_l = \frac{[\alpha_1 \cdot yd_{l-1} + \alpha_{rl} \cdot v_{l-1} + \alpha_{m1} \cdot m1_{l-1} + \alpha_{CBDCl} \cdot (att_{l-1} + CBDCs_{l-1})] \cdot p}{E(p)} + \alpha_{im} \cdot \frac{c_u}{c_l} \cdot p$	Lower-class HH consumption
23	$c_u = [\alpha_{00} \cdot (1 - r_b) \cdot c_{u-1} + \alpha_7 \cdot yd_{u-1} + \alpha_{ru} \cdot v_{u-1} + \alpha_{m1} \cdot m1_{u-1} + \alpha_{m2} \cdot m2_{h-1} + \alpha_{CBDCu} \cdot (att_{u-1} + CBDCs_{u-1})] \cdot \frac{p}{E(p)}$	Upper-class HH consumption
24	$c = c_l + c_u$	Total consumption
25	$mi = mi_{-1} + el_{cgrs} \cdot (r^* - r^*_{-1})$	Monetary Illusion
26	$nv_l = nv_{l-1} + yd_l - c_l$	Lower-class HH net wealth
27	$v_l = nv_l + l_h + pass_l$	Lower-class HH wealth (gross of loans)
28	$nv_u = nv_{u-1} + yd_u + cg - c_u$	Upper-class HH net wealth
29	$v_u = nv_u + pass_u$	Upper-class HH wealth

30	$v_h = v_l + v_u$	Total household wealth
31	$cg = esr \cdot (pe - pe_{-1}) + el_{cgrs} \cdot (r^* - r^*_{-1})$	Capital gains
32	$\Omega = \frac{wb}{y}$	Wage and salary share to total disposable income
33	$\Omega_{adj} = \frac{[wb \cdot (1 - \Omega_r)]}{y}$	Adjusted wage share to total disposable income
34	$lu_l = nv_l + pass_l$	Lower-class HH gross liabilities
35	$lu_u = nv_u + pass_u$	Upper-class HH gross liabilities
36	$lu_t = lu_l + lu_l$	HH gross liabilities
37	$\mathrm{y}_k = r_m \cdot m2_{h-1} + r_b \cdot b_{h-1} + f_{df} + f_b + cg$	Capital incomes
38	$\delta_{yk} = \frac{y_k}{v_{u-1}}$	Capital income as a percentage of wealth
39	$\delta_y = \frac{(y - y_{-1})}{y_{-1}}$	GDP growth rate
40	$cf = m1_{l-1} - l_{h-1} \cdot (1 - rep) + yd_l - c_l - (h_l - h_{l-1}) - CBDC_{wm}$	Cash-flow of lower-class HH
41	$(m1_l = cf\ ;\ l_h = 0)\ \mathbf{if}\ (cf \geq 0)$ $otherwise\ (m1_l = 0\ ;\ l_h = -cf)$	Lower-class HH's financial position
42	$\lambda_{CBDC} = \frac{yd_l}{yd}$	Share of CBDC credited to lower-class HH

2.3- Portfolio decisions

43	$ehr = esr$	Equilibrium condition on the securities market
44	$b_h = (\lambda_{10} \cdot v_{u-1} + \lambda_{11} \cdot v_{u-1} \cdot r_{b-1} + \lambda_{12} \cdot v_{u-1} \cdot r_{m-1} + \lambda_{13} \cdot yd_{u-1} + \lambda_{14} \cdot v_{u-1} \cdot r_{e-1}) - qe - CBDC_{su}$	Households' holding of bills
45	$m1_u = (\lambda_{20} \cdot v_{u-1} + \lambda_{21} \cdot v_{u-1} \cdot r_{b-1} + \lambda_{22} \cdot v_{u-1} \cdot r_{m-1} + \lambda_{23} \cdot yd_{u-1} + \lambda_{24} \cdot v_{u-1} \cdot r_{e-1}) + \left(\frac{1-\lambda_m}{e}\right) \cdot qe$	Cheque deposits held by upper-class HH
46	$pe = \frac{\lambda_{30} \cdot v_{u-1} + \lambda_{31} \cdot v_{u-1} \cdot r_{b-1} + \lambda_{32} \cdot v_{u-1} \cdot r_{m-1} + \lambda_{33} \cdot yd_{u-1} + \lambda_{34} \cdot v_{u-1} \cdot r_{e-1} + \lambda_m \cdot qe}{ehr}$	Shares price
47	$eh = ehr \cdot pe$	Value of shares held by HH
48	$h_l = \lambda_{cl} \cdot c_l \cdot \frac{p^e}{p}$	Lower-class HH s' holding of cash
49	$h_u = \lambda_{cu} \cdot c_u \cdot \frac{p^e}{p}$	Upper-class HHs' holding of cash
50	$h_h = h_l + h_u$	Total cash holding
51	$m1_h = m1_l + m1_u$	Total cheque deposits
52	$m2_h = nv_u - h_u - m1_u - b_h - eh - att_u + pass_u - mi$	Saving deposits
53	$b_h^{pot} = b_h + qe$	Households' potential demand for bills (QE scenario)
54	$b_d^{pot} = b_h^{pot} + b_b + b_{cb}$	Total potential demand for bills (QE scenario)

2.4- Commercial banks

55	$l_s = l_f + l_h$	Supply of bank loans
56	$m1_s = m1_h$	Supply of cheque deposits
57	$m2_s = m2_h$	Supply of saving deposits

58	$f_b = r_{l-1} \cdot l_{f-1} + r_{lh-1} \cdot l_{h-1} + r_{b-1} \cdot b_{b-1} - r_{m-1} \cdot m2_{s-1} - r_{a-1} \cdot ad_{-1} + r_{h-1} \cdot (hb_{d-1} - hb^*_{d-1})$	Banks' profits
59	$hb_d = \rho_1 \cdot m1_{s-1} + \rho_2 \cdot m2_{s-1} + (1-\rho_1) \cdot \left(\frac{1-\lambda_m}{2}\right) \cdot qe + (1-\rho_2) \cdot \left(\frac{1-\lambda_m}{2}\right) \cdot qe$	Required reserves
60	$b_b^{not} = m1_s + m2_s - l_s - hb_d - (1\ -\ \eta) \cdot att_f$	Notional amount of bills held by banks
61	$b_b = b_b^{not} \cdot \beta + (1\ -\ \eta) \cdot \beta_{CBDC} \cdot att_f\ if\ \left(\left(b_b^{not} \cdot \beta + (1\ -\ \eta) \cdot \beta_{CBDC} \cdot att_f\right) \leq (b_s - b_h) \right)$ $otherwise\ (\ b_b = b_s - b_h\ )$	Bills held by banks
62	$hb^*_d = b_b^{not} \cdot (1-\beta) - (1\ -\ \eta) \cdot \beta_{CBDC} \cdot att_f\ \ if\ \left(\left(b_b^{not} \cdot \beta + (1\ -\ \eta) \cdot \beta_{CBDC} \cdot att_f\right) \leq (b_s - b_h) \right)$ $otherwise\ (\ hb^*_d = b_b^{not} - b_b\ )$	Banks' discretionary reserves
63	$a_d = 0\ if\ \ (b_b^{not} > 0)$ $otherwise\ (\ a_d = \ -b_b^{not}\ )$	Demand for advances

2.5- Government

64	$tax_l = \tau_1 \cdot wb \cdot (1 - \Omega_r) + \tau_3 \cdot m1_l$	Taxes paid by lower-class HH
65	$tax_u = \tau_0 + \tau_1 \cdot wb \cdot \Omega_r + \tau_2 \cdot \left(r_{m-1} \cdot m2_h + r_{b-1} \cdot b_h + fd_f + f_b\right) + \tau_3 \cdot (v_{u-1} - h_{u-1} - pass_{u-1})$	Taxes paid by upper-class HH
66	$tax = tax_l + tax_u$	Total tax revenue
67	$gov = \ \sigma_0 + \sigma_1 \cdot y_{-1}$	Government spending
68	$def = tr + gov + r_{b-1} * b_{s-1} - tax - \ f_{cb}$	Government deficit
69	$b_s = b_{s-1} + def$	Bills issued

2.6- Foreign Sector

70	$im = exp\ (m_0 + m_1 \cdot log\ (exr_{-1})\ + m_2 \cdot log\ (y_{-1})\ + m_3 \cdot log\ (p_{-1})\ )$	Imports
71	$x = exp\ (x_0 + x_1 \cdot log\ (exr_{-1})\ + x_2 \cdot log\ (yF_{-1})\ + m_3 \cdot log\ (p_{-1})\ )$	Exports
72	$yF = yF_{-1} \cdot (1 + gF)$	Aggregate foreign income
73	$tb = x - im$	Trade balance

74	$fr = fr_{-1} + tb$	Foreign reserves

2.7- Central Bank

75	$b_{cb} = b_s - b_b - b_h$	Bills held by the Central Bank
76	$hb_s = hb_d$	Supply of required reserves
77	$hb_s^* = hb_d^*$	Supply of discretionary reserves
78	$h_s = b_{cb} + a_s - \left(hb_s + hb_s^* + att_l + att_u + att_f\right) + fr + pass_l + pass_u + pass_f$	Supply of cash
79	$a_s = a_d$	Supply of advances
80	$f_{cb} = r_{b-1} \cdot b_{cb-1} + r_{a-1} \cdot a_{s-1} - r_{h-1} \cdot (hb_{s-1} + hb_{s-1}^*)$	Central Bank's profit

2.8- Interest rates

81	$r_e = \frac{fd_f + cg}{eh_{-1}}$	Return rate on firms' securities
82	$r_b = r^* + \mu_b$	Return rate on bills
83	$r_l = r^* + \mu_l$	Rate of interest on loans to firms
84	$r_{lh} = r^* + \mu_{lh}$	Interest rate on loans to HH
85	$r_m = r^* + \mu_m$	Rate of interest on saving deposits
86	$r_a = r^* + \mu_a$	Rate of interest on Central Bank advances
87	$r_h = r^* + \mu_h$	Rate of interest on reserves

88	$\mu_l = \mu_{l0} + \mu_{l1} \cdot lev_{-1}$	Mark-up: loans' interest rate
89	$b_{pr} = \frac{b_d^{pot}}{b_s}$	Potential private demand for bills over supply
90	$\mu_b = \mu_{b0} - \mu_{b1} \cdot b_{pr-1}$	Mark-up: bills' return rate

2.9- Labour market

91	$wb = w \cdot n_d$	Wage bill
92	$n_d = \frac{y}{(pr_f \cdot p)}$	Labour demand
93	$n_s = n_{s-1} \cdot (1 + gl)$	Labour supply
94	$un = 1 - \frac{n_d}{n_s}$	Unemployment rate
95	$wh = wh_0 \cdot wh_1 + (1 - wh_1) \cdot \left[\left(1 - \Omega_1 \cdot (un_{-1} - nun)\right) \cdot (1 + pi^e) \cdot wh_{-1}\right]$	Wage rate of skilled workers
96	$w = \beta_w \cdot w_l + (1 - \beta_w) \cdot wh$	Average wage rate
97	$w_l = \rho_l \cdot w$	Minimum wage rate
98	$\mu_p = \mu_{p0} + xi \cdot un$	Mark-up over labour costs
99	$ns_{pot} = ns \cdot (1 - nun)$	Potential labour supply

2.10- Popolation

100	$pop = pop_{-1} + pik \cdot (\delta_y - \delta_k)$	Growth in the share of upper-class households in the total population
101	$low_{hh} = (1 - pop) \cdot ns$	Lower-class households
102	$high_{hh} = pop \cdot ns$	Upper-class households
103	$inm = \frac{yd_r / high_{hh}}{yd_w / low_{hh}}$	Measure of inequality

2.11- Prices and expectations

104	$pr_f = pr_{f-1} + pr_{f-1} \cdot gr_{prf}$	Average labour productivity
105	$pf = \frac{w}{pr_f} \cdot (1 + \mu_p)$	Unit price of private output
106	$p = pf$	General price level
107	$pi = \frac{p}{p_{-1}} - 1$	Inflation rate
108	$pi^e = \psi_1$	Expected inflation rate
109	$p^e = p_{-1} \cdot (1 + pi^e)$	Expected price level

2.12- Minsky variables and indices

110	$q = \frac{esrn}{esr} + elqrs \cdot (1 - r^*)$	Valuation ratio (Tobin q)
111	$lev = \frac{l_f}{l_f + v_f + bv + capsoc}$	Leverage ratio of firms

2.13- Redundant equation

112	$h_h = h_s$	Total holdings of cash

2.14- Scenarios

2.14.1- Pasinetti Rule

113.a	$r^* = \frac{(\sum_{i=0}^{7} gr_{prf-i})}{8} + \frac{(\sum_{i=0}^{7} pi_{-i})}{8}$	Interest rate determinated using Pasinetti rule

2.14.2- CBDC to households

113.b	$CBDC = 0{,}05 \cdot y_{-1}$	Central Bank Digital Currency issued
114.b	$CBDC_l = \lambda_{CBDC} \cdot CBDC$	CBDC credited to lower class households
115.b	$l_{CBDCl} = CBDC_l$	CBDC-related loans to lower-class households
116.b	$CBDC_u = (1 - \lambda_{CBDC}) \cdot CBDC$	CBDC credited to upper class households
117.b	$l_{CBDCu} = CBDC_u$	CBDC-related loans to upper-class households
118.b	$pass_l = pass_{l-1} + CBDC_l$	Lower-class HHs' stock of CBDC-related loans
119.b	$att_l = pass_l$	Lower-class HHs' stock of CBDC
120.b	$pass_u = pass_{u-1} + CBDC_u$	Upper-class HHs' stock of CBDC-related loans
121.b	$att_u = pass_u$	Upper-class HHs' stock of CBDC

2.14.3- CBDC to firms

113.c	$CBDC = 0{,}05 \cdot y_{-1}$	Central Bank Digital Currency issued
114.c	$CBDC_f = CBDC$	CBDC credited to firms
115.c	$l_{CBDCu} = CBDC_u$	CBDC-related loans to firms

116.c	$pass_f = pass_{f-1} + CBDC_f$	Firms' stock of CBDC-related loans
117.c	$att_f = pass_f$	Firms' stock of CBDC

2.14.4- Quantitative Easing

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

2.14.5- Sterilisation of Expansionary Monetary Policy

113.e	$CBDC = 0{,}05 \cdot y_{-1}$	Central Bank Digital Currency issued
114.e	$CBDC_l = \lambda_{CBDC} \cdot CBDC$	CBDC credited to lower class households
115.e	$CBDC_{lm} = CBDC_l$	CBDC credited to lower class households momentary
116.e	$l_{CBDCl} = CBDC_l$	CBDC-related loans to lower-class households
117.e	$CBDC_u = (1 - \lambda_{CBDC}) \cdot CBDC$	CBDC credited to upper class households
118.e	$l_{CBDCu} = CBDC_u$	CBDC-related loans to upper-class households
119.e	$CBDC_{su} = CBDC_{su-1} + CBDC_s$	Upper-class HHs' stock of CBDC

120.e $CBDC_{sl} = CBDC_{sl-1} + CBDC_{l}$ Lower-class HHs' stock of CBDC

2.14.6- Scenario in which the banking sector adjusts its allocation of available liquidity at the end of the period

113.f $$\beta = 0.3 + \frac{\left(\frac{5 \cdot y_1}{bb_{not1}}\right)}{100}$$ Share of notional bills held as bills by banks

Appendix E:

Further robustness analysis

Figure E.1: Pasinetti rule scenarios

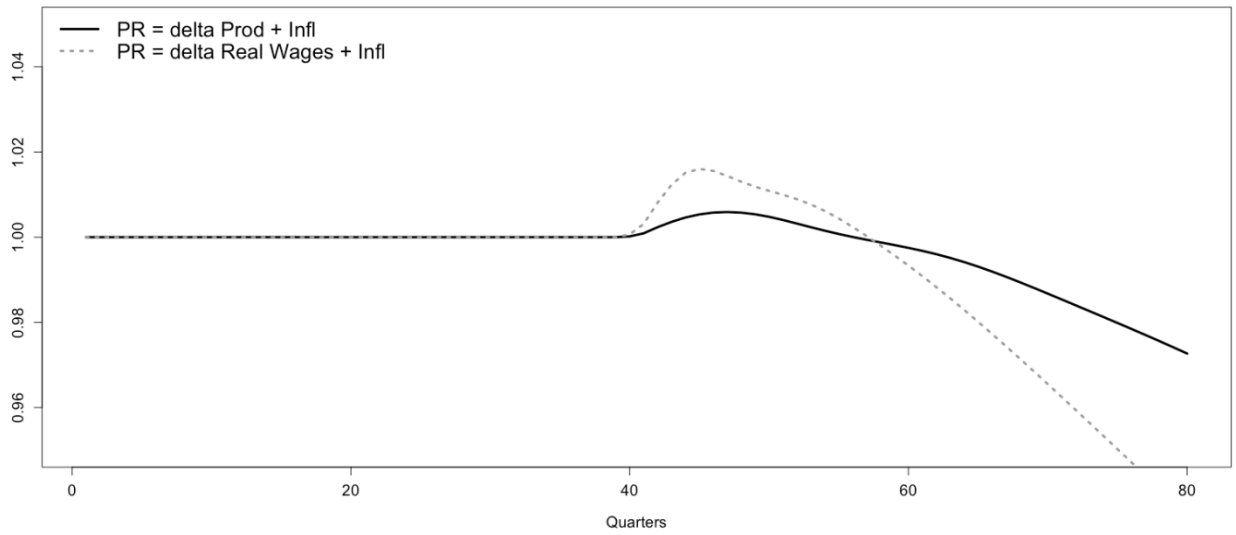


Figure E.2: Sterilized CBC to HH with different marginal propensity to consume CBDC

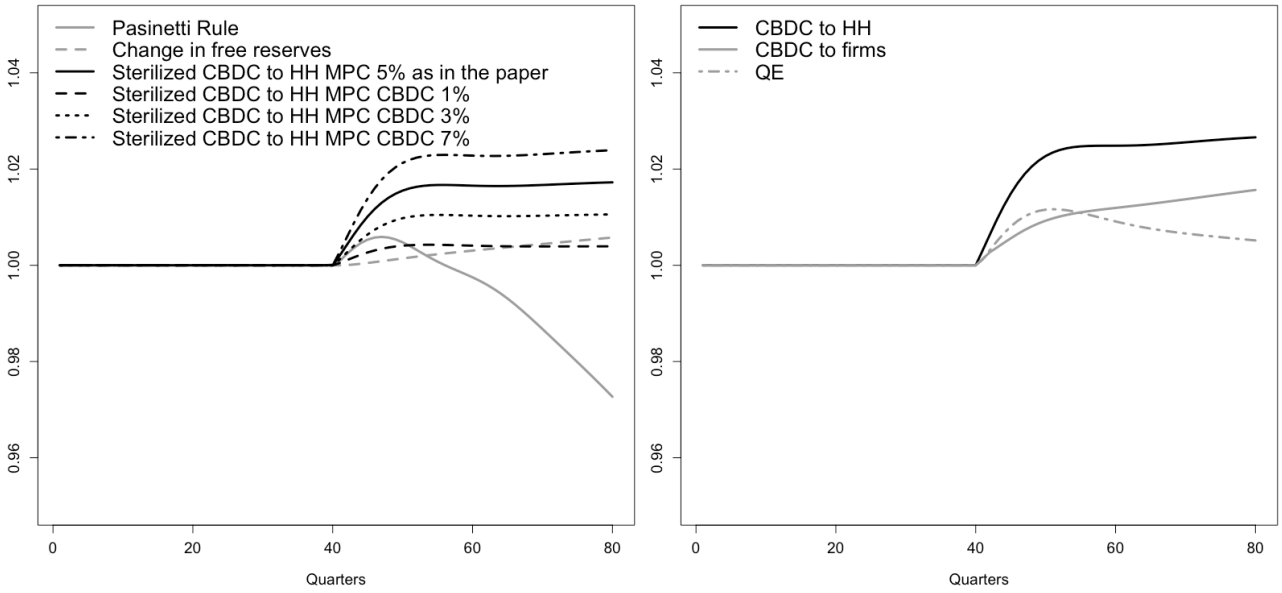


Figure E.3: Sterilized CBC to HH with different marginal propensity to consume wealth

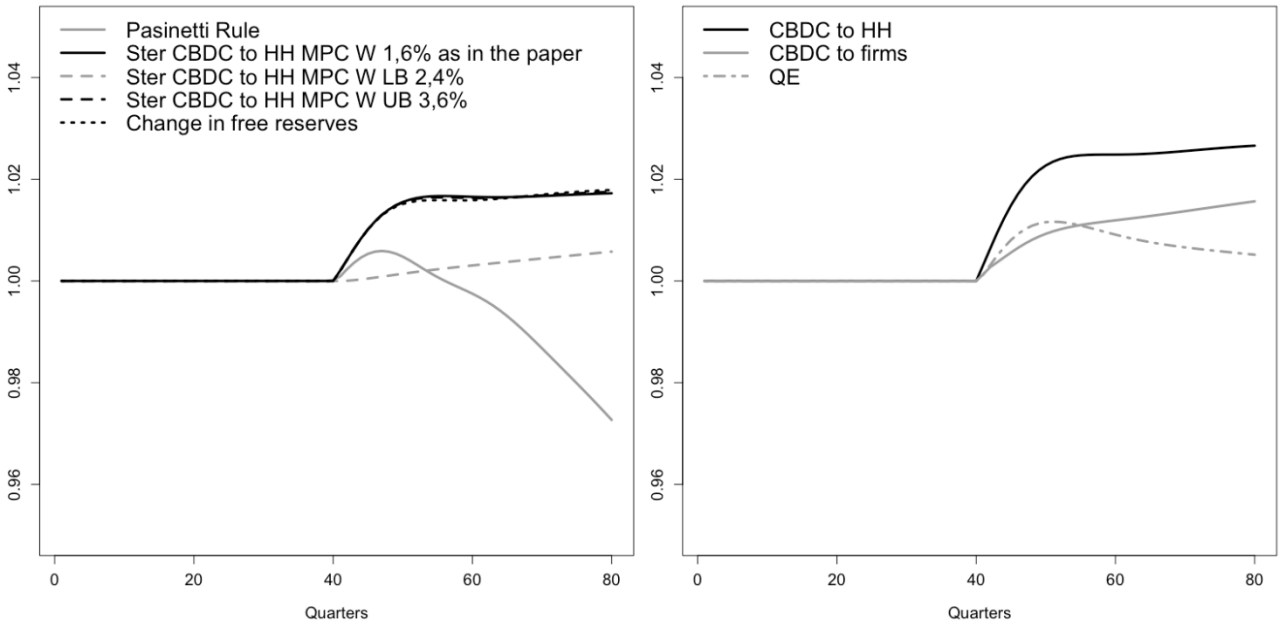


Figure E.4: Scenario with different proportion in the allocation on free reserves in bonds

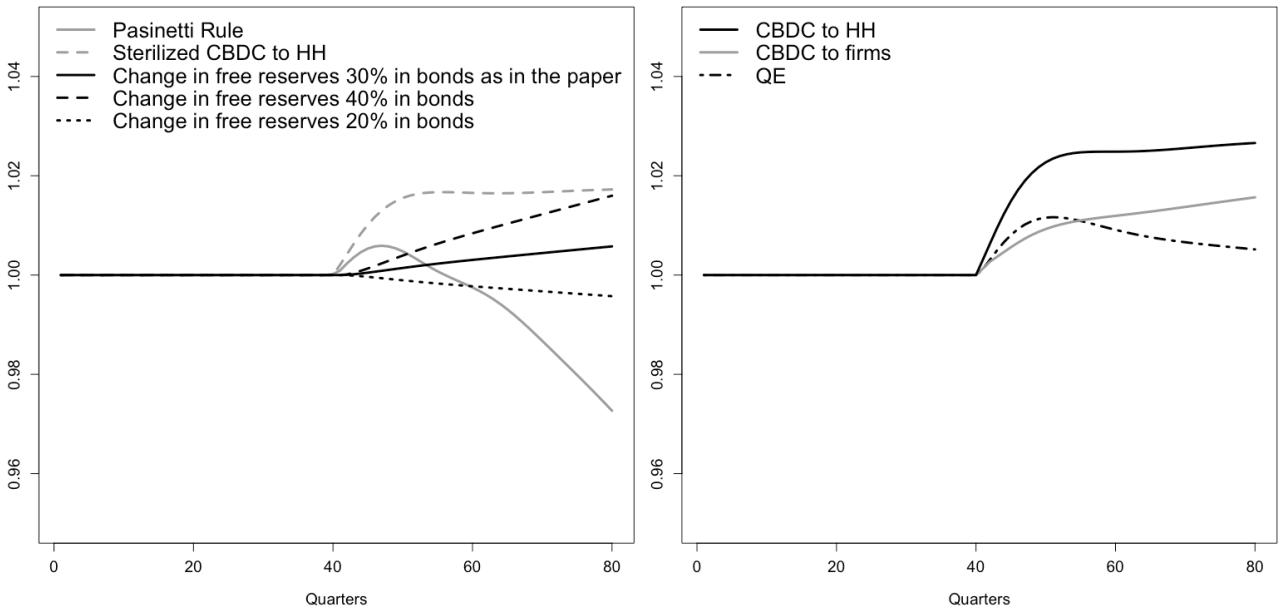


Figure E.5: CBDC to HH with different propensity to consume wealth

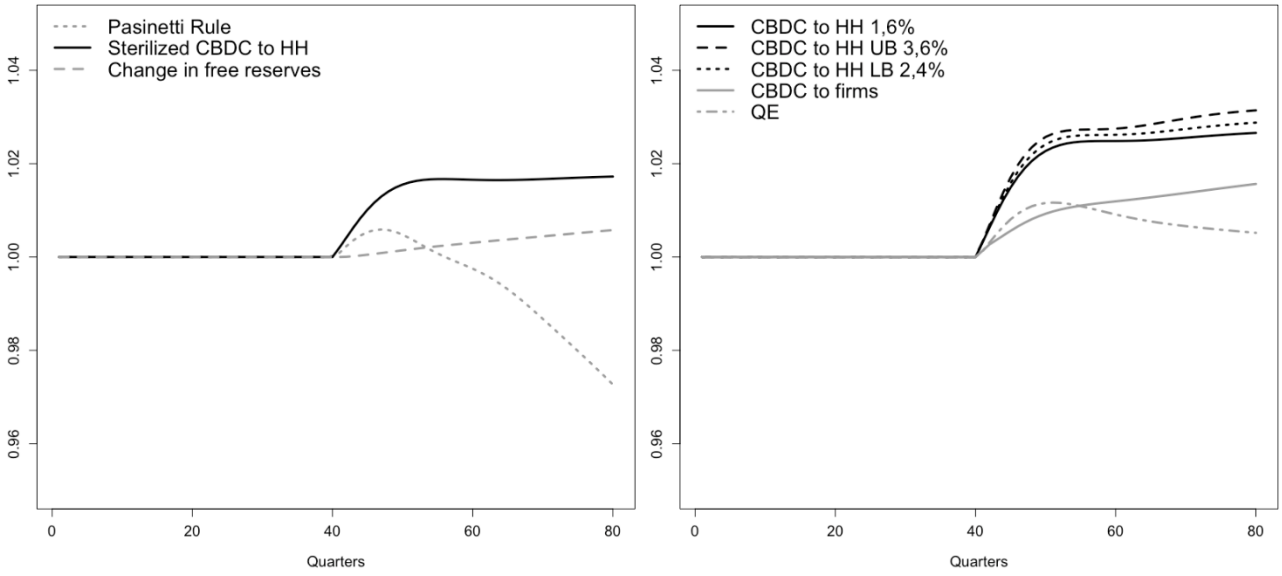


Figure E.6: CBDC to HH with different propensity to consume CBDC

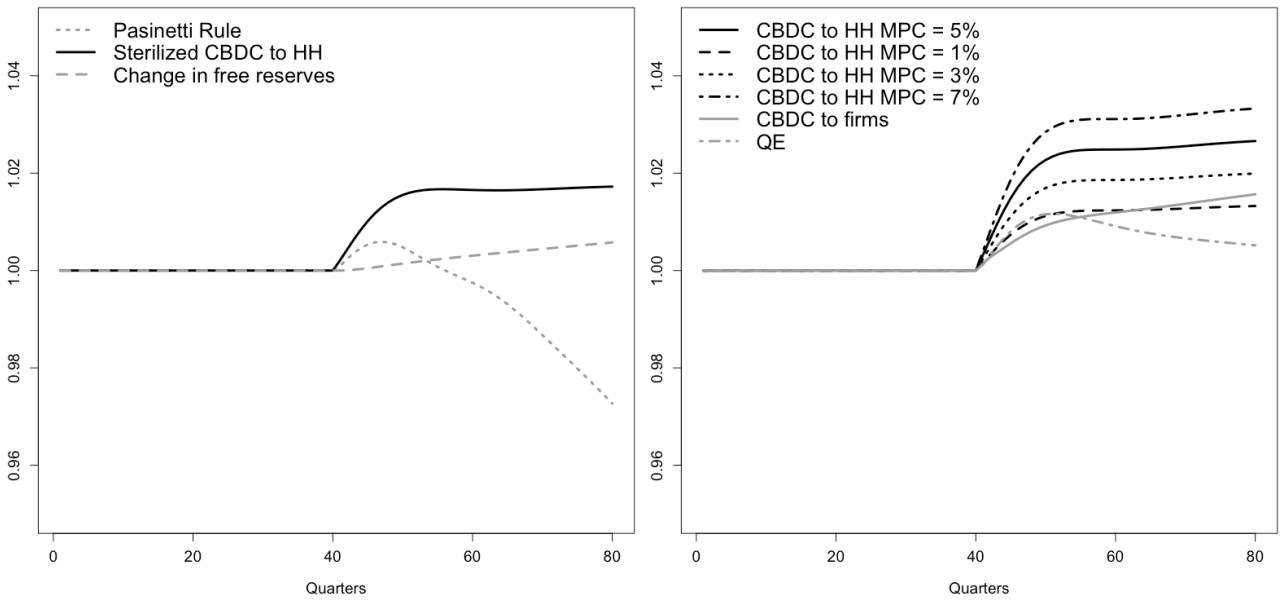


Figure E.7: CBDC to firms with different elasticity of investment to Tobin's Q

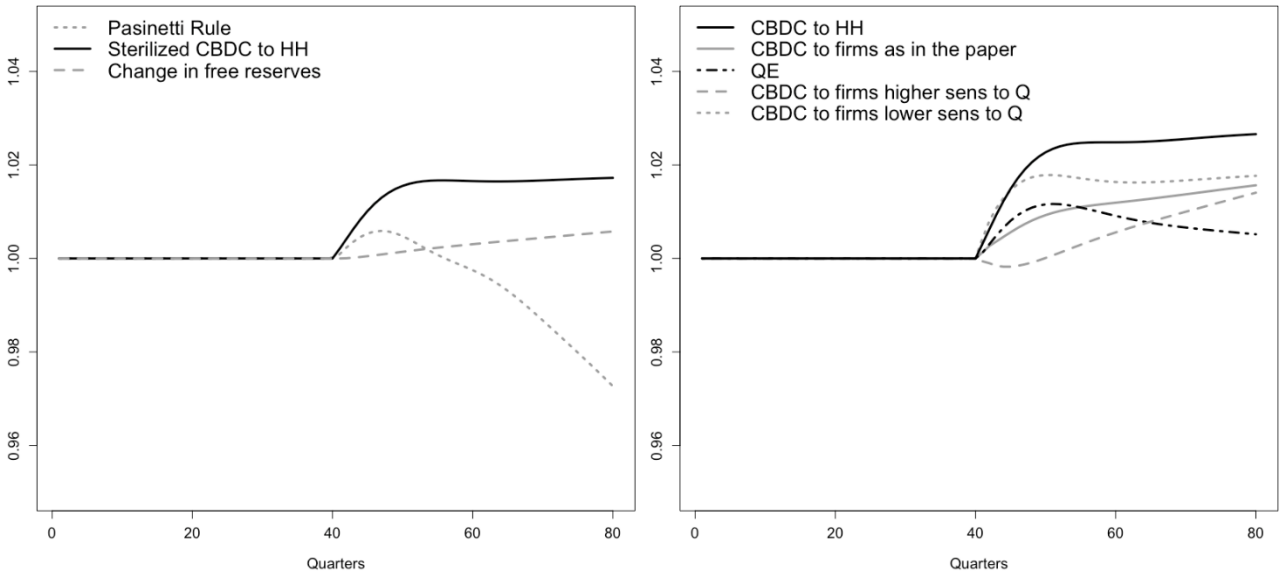
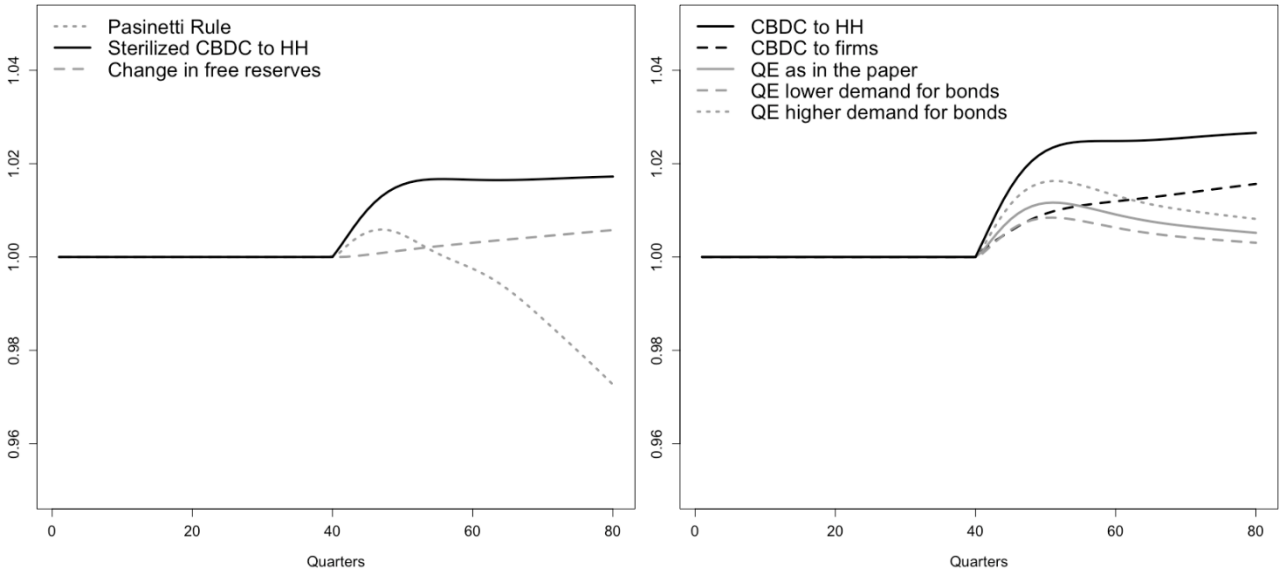


Figure E.8: QE scenarios with different demand of bonds by households



Appendix F:

Description of equations introduced or modified from the original model:

Below is a schematic description of the equations that we have modified or incorporated into the original model of Sawyer and Passarella (2021) used as a starting point for the work proposed here[13]:

Equation 5: Change inserted for the consistent construction of the scenarios presented in the main text.

Equation 11: Change inserted for the consistent construction of the scenarios presented in the main text.

Equation 12: Inserted in order to have more details for scenario construction.

Equation 15: Change inserted for the consistent construction of the scenarios presented in the main text.

Equation 16: Inserted in order to have more details for scenario construction.

Equations 22 and 23: We modified the original equations by aggregating the different assets that compose household wealth and including a single non-asset-specific marginal propensity to consume wealth, in line with the literature presented in the main text.

Equation 25: Inserted in order to have more details for scenario construction.

Equation 31: Change inserted for the consistent construction of the scenarios presented in the main text.

Equation 32: In order to obtain more specific quantities suited to the needs of our model, we modified the original equation and added **equation 33**, which gives us a different measure of the wage share in GDP that is useful for our model.

[13] the number refers to the equations in our model, given in Appendix D above.

Equations 34, 35 and 36: They represent the gross amount of household liabilities, and have been added within the model as they are necessary for the proper functioning of the scenarios proposed and explained in the main text.

Equations 37, 38 and 39: Respectively, these are the equations representing, Capital incomes, Capital income as a percentage of wealth and GDP growth rate. We have included them in the original model because the scenarios we proposed required different specifications from the model used as a starting point.

Equations 40 and 41: We have modified the original equations defining demand for check deposits and demand for loans by lower class households by inserting those presented in the appendix, so that households only borrow from the banking sector if they have no other assets to rely on.

Equation 42: Added in order to have more details for scenario construction.

Equations 44, 45 and 46: Modified from the originals exclusively to fit the proposed scenarios.

Equation 52: Change inserted for the consistent construction of the scenarios presented in the main text.

Equations 53 and 54: Added for the QE's scenario implementation.

Equation 59: We modified the equation to implement the QE scenario, adding a different allocation of resources by households.

Equations 60, 61, 62 and 63: The equations reflect the same principle as the equations presented in the original model, we have only modified them in order to take into account the variations that our proposed scenarios required from the original ones. We refer to both the scenarios in which CBDC is present and the specific scenario in which commercial banks change their decision on how allocate free resources.

Equation 78: Modified from the originals exclusively to fit the proposed scenarios.

Equation 89: Added to the original model in order to build the proposed scenarios.

Equation 110: We have modified this equation by adding a part where we take into account the elasticity of Tobin's Q with respect to the interest rate.

Equation 111: Revised from the original to consistently represent the debt-to-equity ratio of companies, considering the additional code modifications described above that pertain to the two related magnitudes.