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The inflationary consequences of prioritising central bank profits

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Abstract

This paper examines the impact of rising interest rates on central bank profitability. Using a stylized income model, we demonstrate that changes in interest rates in combination with expansive balance sheet policies introduce a cyclical component into the central bank's profit and loss statement. Our findings reveal, however, that while the interplay of such policies may dampen short-term profitability if interest rates rise, they do not undermine a central bank's financial strength, because higher interest rates also raise the value of future seigniorage income. Using data for the euro area, we quantify the consequences for inflation of setting interest rates aimed at mitigating financial losses, showing that such a strategy would lead to substantially higher inflation rates. Overall, our findings confirm that a central bank's willingness to accept temporary losses reflects a commitment to price stability, rather than a hindrance.

JEL: E31; E43; E52; E58; E63

Keywords: Monetary policy; central bank profitability; central bank independence

Non-technical summary

Following a decade of generating substantial income, the profitability of central banks across the world has declined markedly in recent years. For instance, the reported profits of the ECB and the national central banks of the euro area declined by around two-thirds from their peak in 2019 to 2022, and the Federal Reserve reported a loss of $114.3 billion for 2023. The deteriorating financial results are largely the consequence of the rapid rise in interest rates following a long period of balance sheet expansion. Increasing policy rates lead to higher interest expenses on the deposits held by commercial banks. At the same time, the returns on central banks' assets, in many cases consisting primarily of bonds purchased under quantitative easing programs and/or of refinancing operations with long maturities, rise only with a delay. This results in interest expenditures temporarily exceeding revenues.

This paper explores the conditions under which a decline in central bank profitability could have implications for the conduct of monetary policy and, ultimately, price stability. Using a central bank dividend model following Hall and Reis (2015) calibrated with publicly available data on the "Eurosystem's" balance sheet (the consolidated balance sheet of the ECB and the national central banks of the euro area), we demonstrate that expansive balance sheet policies of central banks introduce a cyclical element to profitability. Specifically, by accumulating interest rate risk, a central bank is likely to see substantial profits when rates are low or falling. By contrast, rapid increases in interest rates coupled with large volumes of interest rate sensitive liabilities can lead to significant losses over the course of multiple years, as well as a reduction in the central bank's net equity. We reinforce these conclusions by simulating counterfactual balance sheet scenarios in which the Eurosystem purchased fewer assets (keeping the balance sheet smaller), or extended its reinvestment of principal payments from maturing securities (keeping the balance sheet larger). Furthermore, the model also suggests that the current dip in profitability is mitigated by an increase in the net present value of future seigniorage income. From a net worth perspective, the present decrease in profitability therefore appears to be a temporary setback that does not endanger the financial soundness of the Eurosystem over the medium term.

We further investigate the potential cyclical impact of financial losses on inflation. While central banks always have the capacity to issue new liabilities to cover losses, excessive use of this strategy could diminish the real value of the currency held by the public, ultimately creating additional inflation. Alternatively, a central bank

may be tempted to adjust the interest rates on its existing liabilities to curb losses. We explore the inflationary consequences of such attempts to circumvent temporary losses by establishing a systematic relationship between net income and hypothetical scenarios of short-term interest and inflation rates. These scenarios are constructed to ensure a consistent flow of non-negative income over time.

Our model suggests that if the ECB adopted a "zero-loss" strategy to mitigate accruing losses ex-post, it would need to implement a significantly lower interest rate path compared to the assumptions underlying the ECB's own projections. According to standard elasticities linking interest rates to inflation, the decrease in policy rates to avoid losses over the next years would result in an increase in inflation by approximately 0.5, 0.5, 0.2, and 0.1 percentage points per year over the 2023-2026 horizon. Consistently, we show that under a counterfactual scenario of higher inflation, the additional tightening of monetary policy that would be necessary to bring inflation back to its target would further diminish near-term profitability. Similarly, we show that the ex-ante ability to report losses at times is a precondition to successfully commit to a monetary policy strategy targeting price stability.

These results show that a central bank setting interest rates to avoid losses may face adverse macroeconomic consequences. We conclude that the ability of central banks to deal with adverse financial results by other means – for instance, by building adequate risk provisions, suspending dividend payments to shareholders, or accounting for deferred assets – is crucial for achieving and maintaining price stability.

1 Introduction

The publication of a central bank's financial results typically receives little attention. The dividends that a central bank distributes to its shareholders – most often the government – are the byproduct of its monetary policy, which is usually tasked with ensuring stability in macroeconomic outcomes such as prices, the exchange rate, or the labour market, rather than maximizing profits.

That has changed in recent years. Central banks across the world have reported a dramatic deterioration in profits and in some cases even outright losses. For instance, the annual combined profits of the euro area central banks declined from more than €30bn in 2019 to €12bn in 2022 (Figure 1).[1] The Federal Reserve's net income decreased from a profit of $107.9bn in 2021 to a loss of $114.3bn in 2023.[2] The Bank of England projects a cumulative net present value of QE cash flows between £-50 to £-130bn, and Sweden's Riksbank has already asked for a SEK 43.7bn recapitalization from the government.[3] Consequently, the profitability of central banks has recently attracted wide-spread attention.[4]

This development was the reflection of a major monetary policy shift. Following the burst of inflation in the early 2020s, central banks started raising interest rates to bring inflation back towards their targets. For a central bank, rising interest rates

[1]These figures refer to the pre-tax profits (after transfers to the risk provisions) of the national central banks of the euro area. The ECB and the national central banks (NCBs) are collectively referred to as the "Eurosystem"; institutionally, however, the ECB and the NCBs are separate entities, reporting separate profit and loss accounts. Since the ECB's capital is fully owned by the national central banks of all EU Member States, we use the terms "ECB" and "Eurosystem" interchangeably throughoug this paper, except where explicitly specified. For comparison, the ECB individually generated zero income in 2022 (after a release of €1.6bn from the risk provisions) and a loss of €1.3bn in 2023 (after a transfer of €6.6bn from the risk provisions), following a decade of reported profits accumulating to more than €14.5bn. For the Eurosystem as a whole, Belhocine et al. (2023) project substantial negative income for the for the coming two years, with some national central banks likely to incur losses even longer.

[2]See "Federal Reserve Board announces preliminary financial information for the Federal Reserve Banks' income and expenses in 2023", January 12, 2024. Most Reserve Banks suspended weekly remittances to the Treasury and started accumulating a deferred asset, indicating a period during which earnings are not sufficient to provide for costs.

[3]See "House of Commons Treasury Committee Report on Quantitative Tightening", February 7, 2024, and "The Riksbank proposes that equity be restored to the statutory base level", April 2, 2024.

[4]See, for instance, De Grauwe and Ji (2023) and Buiter (2024).

imply surging interest payments on commercial banks' reserve holdings. But the rates of return on the central bank's assets, such as securities holdings acquired under quantitative easing (QE) programs or longer-term lending operations to banks, are largely locked in for some time, leading to a temporary mismatch between revenues and costs.

While the diagnosis for the decline of central bank profitability is straightforward, the implications for monetary policy are much less clear. This paper analyses conditions under which the decline in central bank profitability could affect monetary policy and price stability. Specifically, we model and project the ECB's profits, relying exclusively on publicly accessible data.[5] The model shows how central banks' expansive balance sheet policies introduced a cyclical profitability component: by accumulating interest rate risk on its balance sheet at the effective lower bound, a central bank is likely to generate significant profits while rates are low, but will encounter temporary losses when interest rates rise quickly. We reinforce these conclusions by simulating counterfactual balance sheet scenarios in which the ECB kept a leaner balance sheet, by not deploying the Pandemic Emergency Purchase Programme (PEPP), or expanded its balance sheet even further, by maintaining the full reinvestment of principal payments in its QE portfolios.

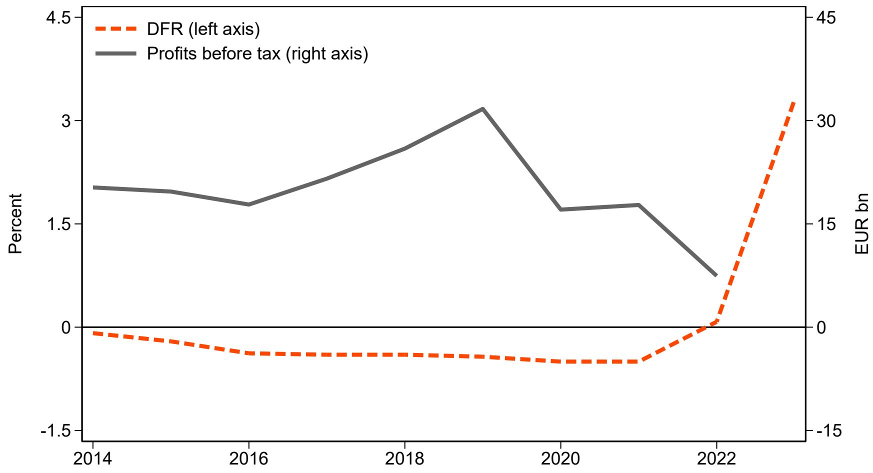
At the same time, the model suggests that viewed through the lens of a central bank's net worth – determined by the present value of its expected future seigniorage income (Reis, 2013; Hall and Reis, 2015) – the current downturn in profitability does not endanger the financial soundness of the Eurosystem over the medium term. From an economic perspective, the current temporary setback in profitability stemming from the rise in interest rates is to a substantial degree offset by a higher net present value of future seigniorage income, illustrating that assessing the soundness of a central banks' balance sheet requires an intertemporal perspective.[6]

We subsequently analyze the cyclical implications of temporary financial losses for inflation outcomes. In this context, it is important to recall the ways in which central banks could deal with losses. First, according to the "mystique of the printing press", central banks are sometimes considered to always be in a position to serve their debts by issuing new currency or reserves (Krugman, 2011). While central banks cannot go "bankrupt" in nominal terms, creating additional nominal reserves

[5]While this approach ensures the reproducibility of our results, it also implies that our findings should not be interpreted as an accurate estimate of the ECB's income.

[6]A prolonged period of negative equity from an accounting perspective may undermine the perception of the central bank's financial independence.

Figure 1: The ECB's policy rate and annual pre-tax profits



Notes: Figure shows the sum of the annual profits of the central banks of the euro area after transfers to/from the provisions for general risks, but before taxes and transfers from other reserves. The sample includes the 18 countries that had adopted the euro as of 2014 (AT, BE, CY, DE, EE, ES, FI, FR, GR, IE, IT, LU, LV, MT, NL, PT, SI, SK).

(or currency) without a concomitant increase in liquidity demand risks a depreciation in the value of the currency. Under the quantity theory of money, this will create inflation, which is effectively a tax on the real value of the currency held by the public.[7] Second, modern central banks in practice typically do not attempt to shore up their balance sheets by issuing additional currency. Instead, they reduce payouts to their shareholders, often the government, or offset losses against accumulated risk provisions. When confronted with comparatively large losses that render such conventional strategies inadequate, central banks may seek (in)direct fiscal support (e.g., the Bank of England or the Swedish Riksbank; see Del Negro and Sims (2015); Reis (2015) for a model-based assessment), or carry uncovered losses forward on their balance sheet (e.g., the Federal Reserve Bank and the ECB). A third possibility consists in lowering the interest expenses that central banks face on their liabilities by reducing policy rates accordingly.

[7] Diluting the real value of the currency is distortionary because money holders can, for instance, shift funds into other (potentially foreign) assets. As a result, there exists in general a point beyond which a higher tax in the form of increasing seigniorage reduces central bank revenues, see e.g. Hall and Reis (2015). Most modern central banks actively aim to sustain sound finances through fiscal backstops to ensure that losses do not compromise their credibility and independence to focus on their mandate, see, for instance, Long and Fisher (2024), Stella (1997), Bindseil et al. (2004) and Ize (2005).

In this paper, we explore counterfactual scenarios in which the ECB followed this third possibility. We assess how the setting of the monetary policy stance would be affected if the central bank would set its policy rates with a view to mitigating losses *ex post*. We model the ECB's dividend distribution following Hall and Reis (2015) and assume that the central bank pays out positive net income as dividends to the government, while reporting any losses in a deferred asset.[8] We then back out the counterfactual implications of a "zero-loss" strategy, under which the central bank sets interest rates to avoid losses instead of reporting them in a deferred asset. Applying the model to the euro area, we show that the ECB would need to set interest rates to substantially lower levels to avoid losses and accept considerably higher inflation rates in return. In particular, a zero-loss strategy would require setting interest rates at 1.7, 1.9, 2.1 and 2.5 percent for the years 2023, 2024, 2025 and 2026, respectively, a significant reduction compared to the interest rates of 3.2, 3.6, 2.7 and 2.5 percent contained in the technical assumptions underlying the ECB's own staff projections from December 2023. According to the average elasticities used in the ECB's inflation projections, such a decrease in interest rates to avoid losses over the next years would result in an increase in inflation by 0.5, 0.5, 0.2, and 0.1 percentage points per year over the 2023-2026 horizon. A zero-loss policy aiming at mitigating losses *ex post* is thereby clearly at odds with the ECB's price stability target.

In an additional counterfactual exercise, we also show that the additional tightening of monetary policy required in a scenario of even higher inflation would further diminish near-term profitability. To do so, we combine our income model with a Taylor (1993)-type interest rate reaction function and study the relation between the possibility of *ex-ante* loss tolerance and the conduct of monetary policy guided by a price stability objective across different inflation scenarios. This suggests that the *ex-ante* ability to report losses at times is a precondition to successfully commit to a monetary policy strategy targeting price stability.

Our results confirm the importance of an appropriate conduct of monetary policy in an environment of temporary losses. The ECB's recent dip in profitability is unlikely to impede its ability to formulate and implement monetary policy, given that from an intertemporal perspective the projected losses are limited compared to its net worth. In this context, the capacity to independently set monetary pol-

[8] In practice, the ECB carries forward uncovered losses on its balance sheet as an asset to be offset against future profits.

icy and divert losses resulting from the appropriate conduct of monetary policy to shareholders – for instance, by suspending dividend payments to governments – is a prerequisite for price stability. In the absence of such independence, the monetary policy space would be significantly constrained ex-ante, and could even give rise to an upward bias in the tolerated ex-post inflation path as central banks could recuperate income via seigniorage and an "inflation tax". These results underline the importance of a central bank's financial independence to prevent potential conflicts between fiscal and monetary objectives.

Related literature The paper contributes to a growing debate about the implications of central bank profitability for the conduct of monetary policy and price stability objectives.[9] Theoretical models of the central bank's balance sheet focus on the role of seigniorage gains in the interaction between monetary and fiscal authorities. Del Negro and Sims (2015) argue that if the public believes that the central bank will allow for higher inflation in the future in order to generate sufficient seigniorage gains to offset present losses, a recapitalisation by the government might be the only solution to avoid ending up in this adverse equilibrium. Relatedly, Reis (2013) shows that the central bank's profit distribution can help select a "good" equilibrium in the context of default risk on government bonds. Corsetti and Dedola (2016) show that when monetary and fiscal authorities operate under strict budget separation, balance sheet purchases create inflation risks. Adrian et al. (2024) discuss central bank losses from a macroeconomic perspective using a dynamic stochastic general equilibrium (DSGE) model, arguing in favor of a forward-looking and risk-based approach to monetary-fiscal policy arrangements on central bank remittances. The importance of such monetary-fiscal arrangements, e.g. regarding outright central bank capitalization by the government in case of accruing losses is also studied by Ize (2005) through the lens of a net-worth model. More recently, Fornaro and Grosse-Steffen (2024) argue that the transfer of seigniorage gains relaxes the government's budget constraint and thereby allows lowering distortionary capital taxes, in turn attracting more capital flows that can mitigate fragmentation risks. In all of

[9] Recently, a broad discussion about how to address the decline in central bank profitability has emerged. Proposals range from ceasing interest payments on banks' reserve holdings, see e.g. a recent VoxEU article by De Grauwe and Ji (2023), to outright capital injections by central banks' shareholders: Germany's federal audit office argued, for instance, that the losses by the Bundesbank would necessitate a fiscal recapitalisation (Bloomberg, June 2023) while Buiter (2024) extends the argument to the Eurosystem.

these cases, monetary policy faces a trade-off between macroeconomic stabilisation and its own profitability.

The empirical literature finds some evidence that central banks operate on this trade-off, although with mixed results. Wang and Zwinkels (2024); Perera et al. (2013); Pinter (2008) and Stella (2008) find positive correlations between central banks' financial strength and macroeconomic outcomes, in particular on inflation. Goncharov et al. (2021) show that the profit distribution of central banks exhibits a discontinuity at zero, and find evidence that central banks aiming to report small profits instead of small losses appear more likely to keep interest rates at too-low levels and accept higher inflation outcomes. Benecká et al. (2012), on the other hand, find that the correlation between financial strength and inflation is weak and sensitive to the specific modelling context.

Our findings on the transitory nature of projected ECB losses are consistent with recent related studies, such as the works by Belhocine et al. (2023) who focus on the combined Eurosystem and individual NCB income, and Cecchetti and Hilscher (2024) who discuss central bank losses in the context of the consolidated government balance sheet.[10] Both studies conclude that monetary policy decisions should not be affected by profitability considerations, particularly given the modest size of projected losses compared to overall profitability, as noted by Cecchetti and Hilscher (2024). Our study provides analytical support to these arguments by examining the projected ECB losses in a quantitative framework, and the adjustments to the monetary policy stance required to avoid them.

The remainder of this paper is organised as follows. Section 2 presents some stylised facts on the Eurosystem's profitability. Section 3 explains the model and describes the data. Section 4 presents the simulation results and Section 5 concludes.

[10] The derivation of average yields earned on the ECB's bond holdings depicts the main quantitative difference between both approaches. While Belhocine et al. (2023) and Cecchetti and Hilscher (2024) implicitly assume that the bond portfolios are rolled over and reinvested at the prevailing market yield, we approximate the portfolio return based on a granular breakdown of the acquired securities yields, weighted by the volume of gross purchases in each month (time-series weighting), as well as the outstanding amount of each bond held in the portfolio and the number of months for which the bonds were traded on the market during the purchase periods (cross-sectional weighting). See section 3 for details.

2 Stylized facts

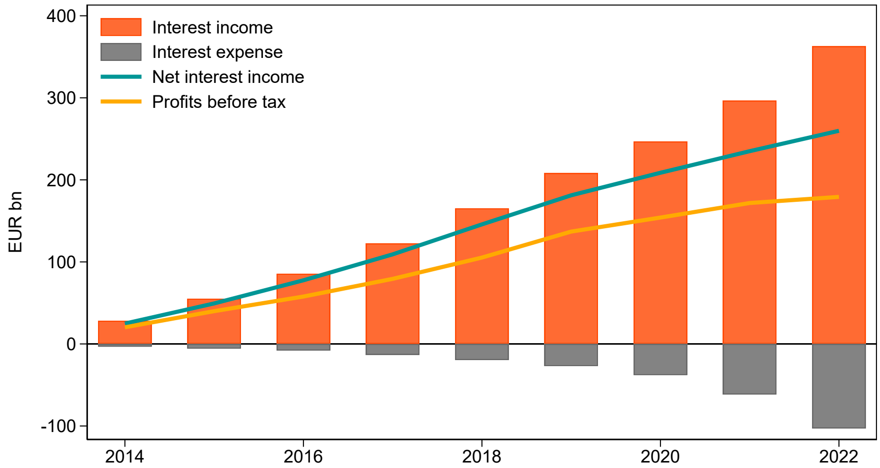
In the euro area, the recent decline in central bank profits followed a decade of substantial profitability. Profits reached their peak in 2019, with the ECB alone reporting €2.4bn, and the national central banks reporting over €30bn in profits before taxes (Figure 1). Cumulatively, over the span from 2014 to 2022, the Eurosystem collectively generated about €190bn in profits before taxes (Figure 2). As interest rates started rising, however, interest expenses also started increasing, with interest expenses in 2022 alone almost reaching the cumulative costs over the preceding eight years.

In recent years, Eurosystem income has been primarily determined by its monetary policy operations. On the one hand, the public and private sector securities held for monetary policy purposes generated a return of around €20bn in 2021, the year before the Governing Council began to raise interest rates, rising to more than €34bn in 2023.[11] On the other hand, the Eurosystem's refinancing operations accounted for a net expense of €19bn in 2021, mainly because banks were able to borrow at below-zero rates under certain conditions during the COVID-19 pandemic.[12] With the deposit facility rate (DFR) and main refinancing operations (MRO) rate – to which the interest rates on the third TLTRO series has been anchored – rising into positive territory, and the recalibration of the TLTRO-III pricing in November 2022, interest income from refinancing operations rose to €26bn in 2023. As the TLTRO-III operations mature, banks may eventually begin borrowing again through standard refinancing operations at the MRO rate, increasing the profitability of the short-term refinancing operations, largely free from interest rate risk.

[11] Based on the net interest income reported by national central banks in their annual reports; for 2023, the numbers does not yet include the results of the central banks of Cyprus, Latvia, Luxembourg, Slovakia, and Slovenia, as their financial statements were not available at the time of writing.

[12] Losses in the Eurosystem refinancing operations are a relatively rare occurrence. Typically, the interest rates applied to refinancing operations, including the targeted longer-term refinancing operations (TLTROs), are variable and pegged to the ECB's key policy rates. When the ECB adjusts its policy rates, the rates on these borrowing operations are re-calibrated accordingly, effectively shielding them from interest rate risk. However, in the third series of TLTROs, banks could access funds from the Eurosystem at rates that could drop as low as -1 percent. Since the majority of this liquidity was held by the banks in the ECB's deposit facility, which at that time offered a negative interest rate of -0.5 percent, the banking sector was able to realize a margin of 50 basis points on each unit of TLTRO-III borrowing during the special interest rate period. See recent ECB communication here.

Figure 2: National central banks' cumulative interest income and profits



Notes: Cumulative interest income and expenses starting from 2014 for the national central banks of the 18 countries that had adopted the euro as of 2014 (AT, BE, CY, DE, EE, ES, FI, FR, GR, IE, IT, LU, LV, MT, NL, PT, SI, SK).

The substantial gross income from monetary policy operations, however, needs to be evaluated against the cost of funding those assets. Currently, roughly half of the Eurosystem's balance sheet is funded by central bank reserves on which it pays the deposit facility rate.[13] Between 2014 and 2022, the negative deposit facility rate implied that the Eurosystem *received* a cumulative €60bn income on those reserves.[14] However, the rising policy rates since mid-2022 have mechanically increased reserve remuneration from a net benefit of more than €16bn in 2021 to a cost of almost €7bn in 2022 and €127bn in 2023.[15]

[13]In an environment of ample reserves, remuneration of commercial banks' deposits held with the central bank is crucial for the implementation of monetary policy. Without interest on central bank reserves, the abundance of liquidity pushes money market rates down, thus interfering with the setting of the monetary policy stance. Interest on reserves ensures that banks are no longer willing to lend in the money market at rates that are lower than the remuneration rate they receive from the central bank, which establishes a floor under money market rates.

[14]Cumulative interest rate payments are computed over the period during which the DFR was below 0 percent (June 2014 - July 2022). The results take into account that over the period 30 October 2019 - 8 September 2022 the Eurosystem operated under a two-tier system for reserve remuneration under which 6 times bank's minimum reserve requirements (MRR) were exempt from negative remuneration if placed in the current account. In addition, MRR were remunerated at the MRO rate during this period.

[15]Reserves held in fulfilment of the MRR were remunerated at the MRO rate until December 2022, between December 2022 and September 2023 at the DFR and from September 2023 they

The rising policy rates are thus immediately translated into higher interest rate expenses, but the transmission to increased returns on the Eurosystem's fixed-income portfolio is delayed. This discrepancy arises because the interest income from securities with fixed coupon rates increases only when maturing bonds are replaced with higher-yielding bonds. An exception are the returns on floating-rate notes or inflation-indexed bonds, which adjust more directly with changes in market or inflation rates. However, these assets play only a minor role in the European bond market relative to fixed-coupon bonds. Accordingly, the net interest income on the Asset Purchase Programme (APP) and the PEPP portfolios rose only marginally from 0.5 percent in 2021 – the year before the first rate hike – to 0.8 percent in 2023. The average income on the refinancing operations, which are linked to the policy rates, was somewhat more responsive, rising from -0.9 percent in 2021 to 3 percent in 2023. Nevertheless, the adjustment in the return on assets stands in stark contrast to the surge in the cost of funding those assets with central bank reserves, which reached a peak at 4 percent in September 2023. As a result, the Eurosystem's interest expenditures have surged at a rate that far outpaced the income generated from its asset holdings.

3 Methodology and Data

3.1 The Income Model

We model the central bank's real income y_t paid as dividends to the government according to a stylized version of a per-period income statement:

$$y_t = \frac{r_t^b B_t + i_t(A_t - L_t) - i_t^*(A_t^n - L_t^n)}{P_t}, \tag{1}$$

where the balance sheet contains bonds B_t which yield a fixed return equal to r_t^b, as well as other assets A_t (e.g., refinancing operations) and other liabilities L_t (e.g., government deposits and central bank reserves) that are remunerated at a rate (close to) the policy rate, denoted by i_t. For completeness, we also include assets and liabilities that do not receive remuneration (A_t^n and L_t^n) and set $i^* = 0$. We divide the nominal income stream by the price level P_t to obtain a real income stream.[16]

no longer receive interest. Moreover, when the DFR is below 0 percent, the current account is remunerated at the DFR, while it is remunerated at 0 percent otherwise.

[16] In practice, the ECB conforms to established accounting conventions and reports its income in nominal terms. However, translating income into real terms is illustrative in the context of

Following Hall and Reis (2015), we assume the central bank to only pay out positive net income as dividends to the government, while reporting any losses in a deferred asset D_t. The central bank thus does not provision for future losses, such that dividend payouts are given by:

$$d_t = \max(y_t - D_{t-1}, 0), \tag{2}$$

where d_t are per-period dividends to the government and the deferred asset D_t measures the backlog of negative net income realizations that have not yet been covered by successive positive income realizations. The reduction of the deferred asset thus occurs progressively as the central bank suspends dividend payments to the government in any period where the central bank's profits fall short of the cumulative deferred asset. Dividend payments to the government will recommence only after the entirety of the deferred asset has been offset by subsequent profits. It follows that the law of motion for the deferred asset is given by:

$$D_t = \min\left(\bar{D}, D_{t-1} - \max(y_t - d_t, 0) + \max(-y_t, 0)\right) \tag{3}$$

with $\bar{D}$ describing an exogenous upper limit to the deferred asset.[17] The first (second) max operator describes the decline (increase) in the deferred asset in case of positive (negative) profits.

In the model, the inclusion of a deferred asset represents an accounting convention that serves to preserve the central bank's gross capital buffer position.[18] At first sight this maintains the central bank's funding structure thereby eliminating the need for a recapitalization to address a potential negative capital position. However, it is important to recognize that the deferred asset is non-interest-bearing, which consequently diminishes the central bank's capacity to generate revenue. When losses, and thus the deferred asset, are substantial, the central bank may find itself unable to generate sufficient income to meet its debt obligations, leading to a scenario where the deferred asset accumulates over time. This situation is equivalent to the highly unusual situation in which the central bank has a negative net worth

the paper's objective as it accounts for the deflationary impact of elevated inflation on the central bank's losses.

[17] In the following analyses, $\bar{D}$ is set at a sufficiently high level such that the minimum always turns out as the per-period holdings of D_t.

[18] The deferred asset is an accounting convention to cover negative net income expenses, but does not consider the impact of losses resulting from a marked-to-market valuation of the balance sheet.

– defined by the net present value of expected future dividends – and would necessitate a recapitalization from the government. This situation is taken into account by the exogenous upper limit of deferred asset holdings $\bar{D}$ and investigated in more detail in Section 4.

3.2 Data

The ECB's real income results from the difference between the returns earned on various asset classes and the costs associated with the remuneration of the liabilities, as per Equation 1. To forecast the ECB's income, we account for each category of assets and liabilities listed on the ECB's consolidated balance sheet, making assumptions about their future trajectory as well as their projected annual rate of return, as summarised in Table 1 and 2.[19]

The income projections are derived by making use of several data sources. Specifically, we deploy market-based information from Bloomberg and iBoxx, which includes estimates of the €STR forward curve for December 2023 and realized yields for bonds held in the ECB's QE programs. Moreover, we include publicly accessible data, which encompass balance sheet figures and income statements, information on the outstanding volume of each bond from the ECB's eligible collateral list, insights from the ECB's Survey of Monetary Analysts (SMA), as well as the ECB's macroeconomic forecasts as of December 2023.[20]

Policy rates

We assume that the ECB policy rates follow the forward rates implied in the euro Overnight Interest Swap (OIS) market. Using OIS quotes from Bloomberg, a smoothing spline is fitted to the implied zero rates to derive the spot curve at a daily grid starting 30 days in the future from the respective cutoff date.[21] Instantaneous forward rates are derived from the interpolated spot curve and averaged to arrive at the annual forward €STR. We take the forward-curve implied €STR as a

[19] For reference, see the 2023 consolidated Eurosystem balance sheet here. Annual series are derived by averaging values for both balance sheet components and the corresponding return and cost series.

[20] The December 2023 ECB projections can be accessed here and the December 2023 Survey of Monetary Analysts here.

[21] The cutoff date for the December 2023 ECB projections was on 23 November 2023.

proxy for the DFR and assume that the MRO rate stands 0.50 percentage points above the DFR until September 2024 and 0.15 percentage points afterwards.[22] The marginal lending facility (MLF) rate is assumed to stand 0.25 percentage points above the MRO rate.

Bond portfolio

Since the bonds purchased under the APP and the PEPP have been the primary source of ECB interest income in recent years, our assumptions for these portfolios deserve greater detail (asset $A7.1$ on the ECB balance sheet, corresponding to B_t in our income model). We project the volume of the bond holdings in these portfolios in line with the median expectations implied by the ECB's SMA. The survey-based trajectory implies a decline in portfolio holdings over the coming years, consistent with the recent decisions by the Governing Council to reduce the QE portfolios.[23]

The internal rate of return on these portfolios must be approximated since neither the security-level portfolio composition nor the purchase yields are publicly available. However, the ECB discloses a list of public and corporate sector securities held in the portfolios under its securities lending facility. In order to approximate the return on the portfolios, we start from this list of bonds and collect their average monthly yields since the start of the asset purchase programmes. We then approximate the aggregate portfolio return in three steps.

First, we account for the purchase pace over time, acknowledging that ISINs that were trading during months with high purchase volumes are likely to have a greater weight in the portfolio than ISINs that were only available during months with low purchase volumes. Specifically, we compute for each ISIN n issued in country c and asset class k a purchase-volume weighted average yield over the period of purchases (October 2014 - December 2024), considering the total volume of bond purchases in any given month during the life of each bond, $\text{Purchases}_{n,t}$, relative to the total aggregate volume of purchases during the life of each bond $\sum_{t=1}^{T} \text{Purchases}_{n,t}$. We then multiply the monthly, ISIN-specific, purchase shares in a given month with the

[22] The adjustment in the spread between the MRO rate and the DFR in September 2024 is in line with the outcome of the ECB's operational framework review, see here.

[23] In December 2022, the Governing Council decided to not reinvest all of the principal payments from maturing securities in the APP from March 2023 onwards, and in June 2023 decided to stop reinvesting in full as of July 2023. In December 2023, the Governing Council announced its intention to reduce the PEPP portfolio by €7.5bn per month on average over the second half of 2024, and to discontinue reinvestments under the PEPP at the end of 2024.

ISIN-specific yield in that month, and sum over all months during which a bond is outstanding to obtain the bond's purchase-volume weighted yield:

$$\overline{\text{Yield}}_{n,c,k} = \sum_{t=1}^{T} \frac{\text{Purchases}_{n,t}}{\sum_{t=1}^{T} \text{Purchases}_{n,t}} \text{Yield}_{n,c,k,t}. \tag{4}$$

Second, we use the purchase-volume weighted yield to approximate the return on the aggregate QE portfolios holdings by weighting the yields by the bonds' relative outstanding amount, a_{nt}, and the number of months that the bond was traded on the market during the period of asset purchases, m_n. Weighting the individual bonds by their outstanding amount, a_{nt}, reflects that the ECB distributed its purchases in a market-neutral manner across the outstanding universe of bonds. This means that we assume that in each month the ECB purchased a fraction of all eligible bonds equal to the fraction of each bond's outstanding amount relative to the overall bond universe. The weights based on the number of months that a bond was active during the period of purchases, m_n, reflects that a security which was traded throughout the entire time in which the ECB bought bonds likely takes up a larger share in the portfolio compared to a bond which was issued only shortly before the end of the purchase phase. Specifically, we compute:

$$r^b_{c,k,t} = \sum_{i}^{I} \frac{m_n a_{n,t}}{\sum_{n=1}^{N} m_n a_{n,t}} \overline{\text{Yield}}_{n,c,k} \tag{5}$$

The time variation in the projected portfolio return therefore derives solely from the composition of outstanding bonds: as the outstanding amount of bonds a_{it} drops to zero upon maturity, the average return on the remaining holdings is re-weighted.[24]

Third, we consider that the ECB distributed the aggregate purchase volumes of public sector bonds across countries according to the euro area member states' subscription to the ECB's capital.[25] Accordingly, for public sector bonds, we apply each country's capital key share ck_c as weights to generate the aggregate portfolio return for public sector bonds $r^b_{\text{public},t} = \sum_c^C ck_c r^b_{c,\text{public},t}$. Purchases of corporate sector bonds were distributed in proportion to the eligible outstanding amounts,

[24]During 2024, redemptions in the PEPP portfolio were still reinvested in full until June and in part until December; beyond 2024, the Governing Council intends to cease reinvestments. We assume that these reinvestments continue to be conducted in proportion to the outstanding amounts of eligible bonds, and occur at the yields on those bonds observed in June 2024.

[25]See the ECB's FAQ on the Public Sector Purchase Programme.

such that an additional weighting by country is not necessary.[26] Finally, we combine the public and private sector portfolio returns with a ratio of 92 percent to 8 percent:

$$r_t^b = 0.08r_{private,t}^b + 0.92r_{public,t}^b \tag{6}$$

Refinancing operations (repos)

The second-largest individual asset on the ECB's balance sheet in recent years were the TLTROs (captured under asset $A5$ in the Eurosystem's consolidated balance sheet, corresponding to item A_t in Equation 1). However, their size has declined rapidly from a peak of more than €2.1tn in 2022, and we assume that the remaining outstanding TLTRO-III operations are rapid at maturity in 2024. To capture the return on these operations, we calculate the average TLTRO-III borrowing rate per operation, accounting for the special interest rate periods between June 2020 and June 2022, the recalibration in November 2022, and early repayments by banks, as well as the €STR forward curve to approximate the applicable policy rates until the end of 2024. We consider that 92 percent of participating banks meet the lending benchmark, which implied a borrowing rate equal to the DFR (see ECB, 2022).[27] Regarding the return from lending to euro area credit institutions for the regular monetary policy operations denominated in euro (MROs and LTROs), we assume that all future operations have a borrowing rate equal to the MRO rate.

Remaining assets and liabilities

For the remaining assets, we make a series of simplifying assumptions. We assume that the volume of gold and foreign exchange (FX) holdings remains nominally unchanged (assets $A1$, $A2$ and $A3$ in the ECB's accounting framework). We assume zero returns on gold holdings and a return on marketable securities equal to the DFR.[28] Similarly, other quantitatively minor assets such as the loans to foreign

[26] See the announcement of the CSPP, "ECB announces details of the corporate sector purchase programme (CSPP)", 21 April 2016.

[27] Considering the limited volume of outstanding TLTRO-III operations relative to the overall balance sheet size, and the marginal impact of shifts in the €STR forward curve on the average borrowing rate on these outstanding operations operations, we do not consider the feedback effects resulting from changes in the policy rate path on the TLTRO-III return in the simulations below.

[28] Valuation gains or losses on these holdings are typically set off against corresponding revaluation accounts on the liability side, rather than entering the profit and loss account, unless these items are held to maturity, in which case they are not revalued at all.

central banks under the ECB's liquidity lines or bilateral repo transactions with non-euro area counterparties (asset item $A4$), other bilateral repos mainly related the securities lending facility (asset item $A6$), legacy loans to the central government dating back to pre-euro times (asset item $A8$), and other miscellaneous assets (asset item $A9$) are assumed to remain constant in nominal terms, and generate a return either equal to the DFR, or remain unremunerated.

We split the liabilities of the ECB into a remunerated (L_t in our model) and a non-remunerated part (L_t^n in our model). The liability side of the balance sheet primarily consists of banknotes (item $L1$) and central bank reserves (item $L2$). We assume that banknotes and reserves held in fulfilment of minimum reserve requirements grow in line with the expected long-run nominal GDP growth rate as contained in the ECB's SMA. The volume of reserve holdings exceeding minimum reserve requirements – the excess liquidity held in the deposit facility – is derived as the residual item after deducting all other projected total liabilities from the projected total assets. Banknotes and minimum reserves are not remunerated, but excess reserves, receive a remuneration rate equal to the policy rate (i_t).[29] Other liabilities to euro area credit institutions denominated in euro and mainly related to the securities lending facility (item $L3$) are also included in category L_t and thus assumed to be remunerated at the DFR. Deposits by the euro area governments as well as other public sector institutions – captured as liabilities to other and non-euro area residents denominated in euro (items $L5$ and $L6$) – receive remuneration equivalent to the €STR minus 20 basis points since policy rates moved into positive territory in September 2022.[30] We therefore include both items in L_t. Like all foreign currency denominated assets, all foreign currency denominated liabilities (items $L7$, $L8$, and $L9$) are included in L_t, consistent with our assumption about the return on FX assets. Lastly, we assume that other liabilities, revaluation accounts, and capital and reserves (items $L4$, $L10$, $L11$ and $L12$) do not receive remuneration by including them in L_t^n.

Notably, our stylized model abstracts from many of the institutional and accounting details relevant for determining and projecting the ECB's net income in practice. For instance, the analysis abstracts from issues related to heterogeneity in loss provisioning and risk-sharing across Member States. Moreover, the model

[29] Since September 2023, minimum reserve requirements – a component of banks' reserve holdings – do not receive remuneration, while before September 2023 (and since November 2022) they received the DFR.

[30] See the ECB press release here.

assumes that the return or cost of foreign assets and liabilities is similar to that of euro-denominated items.[31] The figures should therefore not be interpreted as net income projection for the ECB, but rather as a quantitative scenario for calibrating the model.

4 Simulation Results

In this section, we apply the central bank income model outlined in Section 3.1 to analyse the economic implications of a central bank setting policy rates to avoid expected losses. We first derive a baseline net income projection for the coming years and discuss whether the streak of projected losses would pose a threat to the ECB's long-term financial strength. To this end, we use the model to assess the impact of changes in policy rates on its net worth. We then turn to cyclical implications of central bank losses and conduct two counterfactual exercises to study the relation between central bank profitability and monetary policy. We first assess how the ECB's losses would affect the setting of the monetary policy stance *ex post* if it set its policy rates with a view to mitigating those losses. To this end, we also study the profitability implications of two alternative balance sheet paths, under which the balance sheet is either kept larger or smaller than in our baseline scenario. Second, we combine the income model with a standard Taylor (1993)-type interest rate reaction function to study the relation between the possibility of *ex-ante* loss tolerance and the conduct of monetary policy guided by a price stability objective.

4.1 Long-term impact of central bank losses: a net worth perspective

The recent decline in central bank profitability has led to public discussions about the solvency of major central banks.[32] The ECB values its monetary policy securities holdings at amortized costs subject to impairment, meaning that financial losses

[31] This assumption reduces somewhat the accuracy of the model's predictions. However, considering that foreign currency-denominated items in net terms represent a minority fraction of the ECB's balance sheet, and taking into account that the policy cycles between the ECB and other advanced economies (most items are denominated in the currency of other advanced economies) are generally aligned, the choice to categorize the model into three asset classes and two liability types has limited consequences for projecting overall income.

[32] See, for instance, Buiter (2024).

Table 1: Consolidated balance sheet of the ECB: asset side

Assets (A)	Projection assumption	Remuneration assumption	Model expression
1. Gold and gold receivables	Constant at December 2023 level	Unremunerated	$i^* A_t^n$
2. Claims on non-euro area residents denominated in foreign currency	Constant at December 2023 level	Deposit facility rate	$i_t A_t$
3. Claims on euro area residents denominated in foreign currency	Constant at December 2023 level	Deposit facility rate	$i_t A_t$
4. Claims on non-euro area residents denominated in euro	Constant at December 2023 level	Deposit facility rate	$i_t A_t$
5. Lending to euro area credit institutions related to monetary policy operations denominated in euro			
5.1. Main refinancing operations	Standard refinancing operations projected to follow SMA April 2024 median expectations until 2026Q4, SMA April 2024 long-run nominal GDP growth afterwards. Once projected excess liquidity reaches zero and balance sheet requires renewed expansion because of autonomous factors growth, additional liquidity needs are added.	Main refinancing operations rate	$(i_t + 50bps)A_t$ until September 2024 and $(i_t + 15bps)A_t$ thereafter.
5.2. Longer-term refinancing operations	SMA April 2024 median expectations until 2026Q4, SMA April 2024 long-run nominal GDP growth afterwards. TLTRO-III are assumed to be repaid at maturity and not rolled-over in other refinancing operations.	LTRO at Marginal lending facility rate rate. TLTRO-III at fixed TLTRO-specific rate: 3.03% in 2023 and 3.76% in 2024.	Fixed-rate
5.3. Fine-tuning reverse operations	0		
5.4. Structural reverse operations	0		
5.5. Marginal lending facility	Constant at December 2023 level	Marginal lending facility rate	$(i_t + 75bps)A_t$ until September 2024 and $(i_t + 40bps)A_t$ thereafter.
5.6. Credits related to margin calls	0		
6. Other claims on euro area credit institutions denominated in euro	Constant at December 2023 level	Deposit facility rate	$i_t A_t$
7. Securities of euro area residents denominated in euro			
7.1. Securities held for monetary policy purposes	APP projected to decline in line with the SMA December 2023 projections	Remunerated at a fixed rate determined by the weighted average portfolio.	$r_t^b B_t$
7.2. Other securities	Constant at December 2023 level	Remunerated at a fixed rate determined by the weighted average portfolio.	$r_t^b B_t$
8. General government debt denominated in euro	Constant at December 2023 level	Deposit facility rate	$i_t A_t$
9. Other assets	Constant at December 2023 level	Unremunerated	$i^* A_t^n$

Table 2: Consolidated balance sheet of the ECB: liability side

Liabilities (L)	Projection assumption	Remuneration assumption	Model expression
1. Banknotes in circulation	Long-run nominal GDP growth rate (median expectation in SMA December 2023).	Unremunerated	$i^* L_t^n$
2. Liabilities to euro area credit institutions related to monetary policy operations denominated in euro			
2.1. Current accounts (covering the minimum reserve system)	Long-run nominal GDP growth rate (median expectation in SMA December 2023).	Unremunerated	$i^* L_t^n$
2.2. Deposit facility	Excess liquidity derived as the residual of all other balance sheet items; minimum 0.	Deposit facility rate	$i_t L_t$
2.3. Fixed-term deposits	0		
2.4. Fine-tuning reverse operations	0		$i_t L_t$
2.5. Deposits related to margin calls	0		
3. Other liabilities to euro area credit institutions denominated in euro	Return to end-2007 level extrapolated at long-term nominal GDP growth rate over 24m period, then long-term nominal GDP growth.	Deposit facility rate	$i_t L_t$
4. Debt certificates issued	Constant at December 2023 level.	Unremunerated	$i^* L_t^n$
5. Liabilities to other euro area residents denominated in euro	Return to end-2007 level extrapolated at long-term nominal GDP growth rate over 24m period, then long-term nominal GDP growth.	Deposit facility rate minus 20 basis points	$(i_t - 20bps)L_t$
6. Liabilities to non-euro area residents denominated in euro	Return to end-2007 level extrapolated at long-term nominal GDP growth rate over 24m period, then long-term nominal GDP growth.	Deposit facility rate minus 20 basis points	$(i_t - 20bps)L_t$
7. Liabilities to euro area residents denominated in foreign currency	Constant at December 2023 level	Deposit facility rate	$i_t L_t$
8. Liabilities to non-euro area residents denominated in foreign currency	Constant at December 2023 level	Deposit facility rate	$i_t L_t$
9. Counterpart of special drawing rights allocated by the IMF	Constant at December 2023 level	Deposit facility rate	$i_t L_t$
10. Other liabilities	Constant at December 2023 level	Unremunerated	$i^* L_t^n$
11. Revaluation accounts	Constant at December 2023 level	Unremunerated	$i^* L_t^n$
12. Capital and reserves	Constant at December 2023 level	Unremunerated	$i^* L_t^n$

associated with higher expected policy rates materialize only gradually. Nonetheless, the decline in market value of the ECB's monetary policy securities holdings is substantial, surpassing the recently reported losses by a significant margin. The ECB, for instance, reported an annual decline in the market value of its portfolio from €453bn at the end of 2021 to €385bn at the end of 2023. As the ECB's portfolios account for ca. 9 percent of all securities held for monetary policy purposes in the Eurosystem, the corresponding valuation decline at the euro area level likely amounts to several hundred billions.[33]

However, such a calculation is incomplete, as higher policy rates also increase the seigniorage income that central banks earn from issuing currency. Issuing banknotes incurs close to zero costs and is backed by assets that usually yield a positive return. Over time, the ECB will gradually replace its legacy bond holdings B_t carrying relatively low yields with new assets (refinancing operations or securities) that should earn the prevailing market rate. Historically, the ECB primarily backed the issuance of currency with loans to the banking sector at a rate equal to the MRO rate.[34] This implies that a rise in the level of interest rates not only *lowers* the value of fixed-income securities, but also *raises* the value of issuing banknotes.

Starting from Equation 1, the net worth of the central bank can be represented by the net present value of expected future (nominal) income:

$$NW_t = \sum_{k=0}^{\infty} \mathbb{E}_t \left\{ \frac{P_{t+k} y_{t+k}}{\prod_{\tau=0}^{k} (1 + i_{t+\tau})} \right\}, \tag{7}$$

where $\mathbb{E}_t$ denotes expectations at time t and the expected nominal income $P_{t+k}y_{t+k}$ is discounted by the expected nominal policy rate. The income effect of future policy

[33]Based on the ECB's 2022 and 2023 annual accounts, the market value of the ECB's monetary policy portfolio declined by €55.3bn and €12.5bn between 2021-2022 and 2022-2023, respectively. The ECB held 9.3 percent and 9.0 percent of the total Eurosystem sovereign bond portfolio at the end of both years. To the extent that the ECB's portfolio is representative of the aggregate Eurosystem holdings, these figures extrapolate to more than €500bn in 2022 and more than €100bn in 2023. Appendix 6.2 presents a simple analysis demonstrating a strong correlation between the reported figures and our preliminary estimates derived from the income-based valuation model.

[34]Alternatively, and consistent with the announced changes to the operational framework for implementing monetary policy, the ECB could consider partially accommodating the issuance of currency by adopting a structural portfolio of securities. Although such purchases may introduce additional interest rate risk to the ECB's balance sheet, they would likely yield, on average and in risk-adjusted terms, the risk-free market rate, which is expected to be anchored to the DFR path. In this scenario, our income projections would be slightly lower. However, considering that the spread between the MRO rate and the DFR will be narrowed to 15 basis points, the magnitude of this difference is qualitatively inconsequential for our conclusions.

rate adjustments can be represented by the partial derivative of Equation 7 with respect to the future policy rate i_{t+k}:

$$\frac{\partial NW_t}{\partial i_{t+k}} = \mathbb{E}_t \left\{ \frac{A_{t+k} - L_{t+k}}{(1 + i_{t+k}) \prod_{\tau=0}^{k} (1 + i_{t+\tau})} \right\}, \tag{8}$$

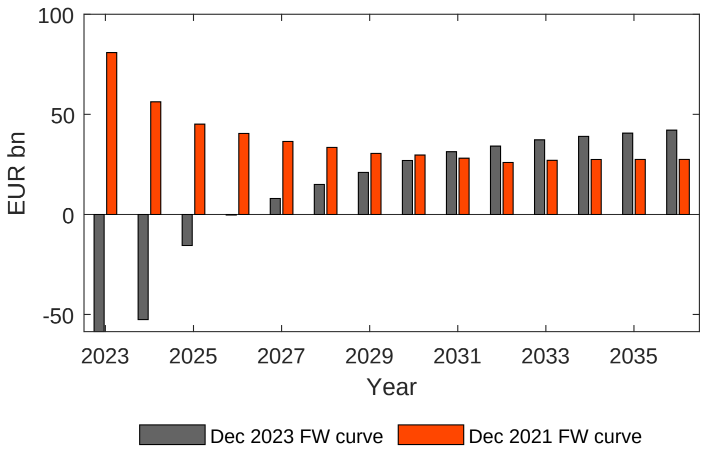
where we set $B_{t+k} = 0$ and $i^*_{t+k} = 0$ without loss of generality (see Appendix 6.1 for the derivations). Equation 8 shows that the income effect of high policy rates is monotonically increasing in the level of future policy rates when $(A_{t+k} - L_{t+k}) > 0$ as the denominator is positive for all conceivable policy rates. Intuitively, an upward shift in the expected future policy path not only increases the expected cost the ECB needs to pay on central bank reserves, but also the expected future return it will earn on its assets which are funded by issuing currency. The income effect of higher policy rates is positive when interest-accruing assets (A_{t+k}) are larger than cost-bearing liabilities (L_{t+k}).

A comprehensive assessment of the impact of higher interest rates on the ECB's net worth thus needs to take into account the full balance sheet, rather than just the partial effect on the value of its bond holdings. We utilize the income model set out above to simulate ECB income for the period from 2024 to 2036, discounting the nominal annual cash flows based on the market-expected future policy rates derived from the €STR forward curve.[35] To gauge the impact of the increase in policy rates, we simulate the model using the forward curve prevailing on 8 December 2021 – the week before the ECB's Governing Council initiated its monetary policy normalisation process – and on 30 December 2023. Figure 3 illustrates the results, revealing a substantial decline in ECB income in the near term. In December 2021, discounted ECB profits for 2024 were expected to reach €56bn. However, the upward movement in the forward curve has reduced the estimated income for 2024 by €109bn, resulting in an expected loss of €53bn. Nonetheless, while the increase in expected interest rates has dampened near-term income, it has significantly raised the expected net present value of medium- to longer-term ECB income: income projections based on the December 2023 forward curve anticipate a sharp recovery in ECB income, surpassing the December 2021 income projection profile in 2030.

The recent decline in central bank profitability is most concentrated in the short- to medium-term, but does not necessarily translate into a substantially lower net worth. Although it takes considerable time before the net present value of the

[35] When discussing the cyclical implications of central bank losses in Section 4.2, we focus on per-period losses and thus no discounting of future cash flows is needed.

Figure 3: Model-based ECB discounted cash flows



Notes: The discounted cash flows are computed according to Equation 7 using the forward curves prevailing on 30 December 2021 and 8 December 2023, respectively.

cumulative expected dividend stream exceeds the corresponding figure evaluated from the perspective of December 2021, it is evident that the near-term setback in profitability resulting from the rise in interest rates is to an extent offset by the higher net present value of future seigniorage income. The net present value of the expected income stream over the coming decade declined by €374bn as a result of the higher (expected) interest rate path in 2023 compared to 2021. However, the difference declines with every additional year added to the projection horizon in which interest rates remain higher than expected in December 2021.[36] This result indicates that a partial revaluation of a central bank's securities portfolio at market prices overlooks an important dynamic of central bank profitability and is therefore unlikely to affect monetary policy in isolation. We thus focus on the implications

[36] We refrain from computing the terminal value of the ECB's income stream, as it would require assumptions regarding changes in the steady-state value of future discount rates, a concept linked to the structure of the euro area economy. Whereas there is empirical evidence that the natural rate of interest in the euro area has increased in the past 2 years (Brand et al., 2024), such estimates are highly uncertain, complicating an assessment of their impact on the terminal value of a central bank's net worth. Instead, we therefore separate Equation 7 into two parts, assuming that the economy returns to its steady state after j periods: $NW_t = \sum_{k=0}^{j} \mathbb{E}_t \left\{ \frac{P_{t+k} y_{t+k}}{\prod_{\tau=0}^{k}(1+i_{t+\tau})} + \frac{1}{(\prod_{\tau=0}^{k}(1+i_{t+\tau}))^j} \frac{y^{ss}}{i^{ss}-g} \right\}$. ECB income is then projected j periods ahead as denoted by the first term, while abstracting from the second term, which requires an assessment on changes in steady state income y^{ss}, the steady state nominal interest rate i^{ss} and the growth rate of the balance sheet g to compute the terminal $\frac{y^{ss}}{i^{ss}-g}$.

for the conduct of monetary policy of a central bank setting policy rates to avoid even temporary losses in the next section.

4.2 Cyclical impact of central bank losses

4.2.1 Ex-post inflation tax under a zero-loss interest rate policy

Baseline scenario

Simulating the model in real, non-discounted terms shows that ECB net income is negative over the 2023-2026 period, with losses reaching approximately €60bn in 2023, and €54bn in 2024 before declining to €0.4bn by 2026 (Figure 4). The cumulative projected loss of approximately €129bn over this period is therefore less than the €190bn profits generated over the main period of net asset purchases from 2014-2022 (Figure 2), and appears even more moderate when also taking the cumulative profits of approximately €74bn projected over the remainder of the decade into account. The main factor driving the expected simulated losses is the interest rate mismatch between the assets – with relatively stable returns at low levels (red line Figure 6) – and the liabilities which have become increasingly costly as reserves are remunerated at the policy rate (red line Figure 9).

Zero-loss interest rate policy under baseline scenario

Nevertheless, a central bank trying to avoid making losses may be compelled to adjust the policy rates accordingly. To trace out the counterfactual interest rate path needed to eradicate accruing losses, i.e. to keep the deferred asset D_t at zero, we define the counterfactual non-negative net income path as:

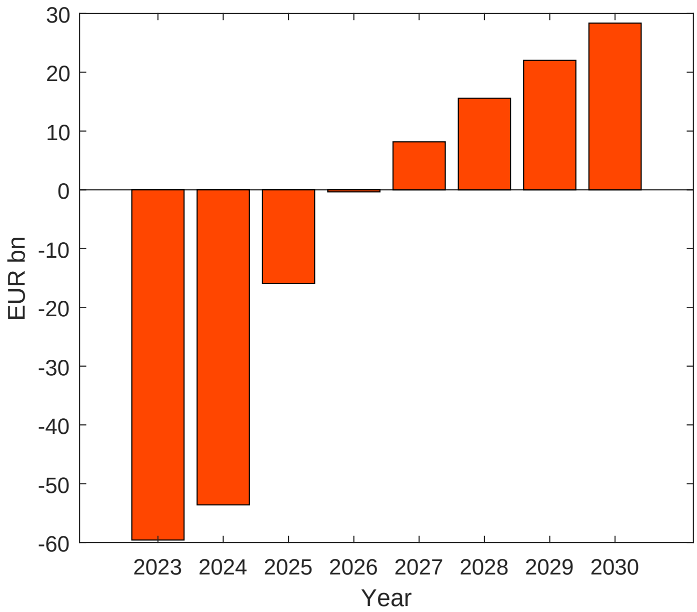
$$\check{y}_t = \max(y_t, 0). \tag{9}$$

Solving Equation 1 for the policy rate i_t and using $\check{y}_t$ yields the counterfactual nominal short-term interest rate path:

$$\check{i}_t = \frac{P_t \check{y}_t - r_t^b B_t + i_t^*(A_t^n - L_t^n)}{A_t - L_t}. \tag{10}$$

The resulting hypothetical path for $\check{i}_t$ that would prevail in the baseline scenario under a zero-loss policy is reported in the left panel of Figure 5 (grey dots). The model results suggest that the ECB would need to set its policy rates to substantially

Figure 4: Model-based ECB net income path - baseline scenario



Notes: Model simulations for ECB net income based on Equation 1.

lower levels relative to what is factored in the baseline scenario (red bars) in order to avoid losses stemming from the mismatch between largely locked-in asset returns and liability costs in an ex-post manner over the coming years. Specifically, the model simulations suggest that short-term interest rates would need to fall to 1.7, 1.9, 2.1 and 2.5 percent in 2023, 2024, 2025 and 2026 respectively, compared to 3.2, 3.6, 2.7 and 2.5 percent over the same period as contained in the technical assumptions underlying the ECB's December 2023 projections.

These lower policy rates would likely have an impact on inflation. We use the ECB's baseline model elasticities to gauge the impact of counterfactually lowering the short-term interest rate on inflation, and define an "inflation gap" $\tilde{\pi}_t$, describing the difference between the hypothetical inflation path $\check{\pi}_t$ prevailing under the counterfactual interest rate path $\check{i}_t$ given by Equation 10 and the projected inflation path π_t in the ECB's 2023 December projections[37]:

$$\tilde{\pi}_t = (\check{\pi}_t - \pi_t) = \alpha(\check{i}_t - i_t). \tag{11}$$

Consequently, the hypothetical inflation rate is given by

$$\check{\pi}_t = \pi_t + \tilde{\pi}_t. \tag{12}$$

[37] We define the inflation rate as $\pi_t = \frac{P_t}{P_{t-1}} - 1$ where P_t reflects the level of the HICP at time t.

We calibrate the elasticity parameter α in Equation 11 to -0.3, in line with the short-term interest rate-inflation elasticity estimated by a suite of ECB models and in the ECB Basic Model Elasticities (BMEs) exercise.[38] According to the ECB model elasticities, the decline in policy rates necessary to avoid losses in the coming years would translate into substantially higher inflation rates. The inflation gap is estimated to be 50 basis points in 2023, 50 basis points in 2024, 20 basis points in 2025 and 6 basis points in 2026, respectively (difference of grey dots and red bars in the right panel of Figure 5).

Zero-loss interest rate policy under alternative balance sheet scenarios

In the following, we discuss two counterfactual scenarios to further assess the impact of the ECB's expansive balance sheet policies on income cyclicality and implications for interest and inflation rates under a hypothetical zero-loss policy. First, we evaluate the potential income effects for the ECB if the PEPP had not been implemented (henceforth the "no-PEPP scenario"). Second, we assume that the ECB continues to reinvest all principal payments from maturing securities purchased under the PEPP and APP in the coming years (henceforth the "no-QT scenario").[39]

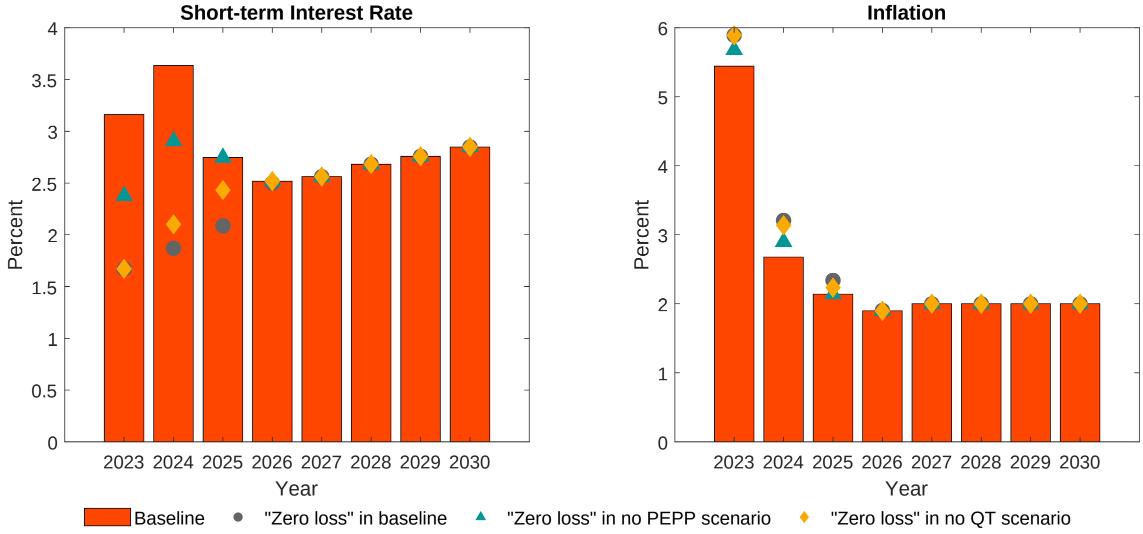
The counterfactual balance sheet scenarios require two additional assumptions. First, we need to determine which liability items to adjust in order to offset the assumed counterfactual change in the size and composition of the monetary policy portfolio. We assume that counterfactual adjustments to portfolio holdings on the asset side of the ECB balance sheet are mirrored in a direct adjustment of banks' reserve holdings on the liability side.[40] As a result, in the no-PEPP scenario, the mechanical reduction of reserves implies a swifter attainment of the minimum level of banks' reserve holdings compliant with minimum reserve requirements. In turn, the ECB balance sheet starts expanding earlier again in this scenario compared to

[38] BMEs are obtained from a suite of macroeconomic models maintained at the ECB and ECB national central banks in the context of the joint forecasting exercises. See ECB (2016) for further technical details on BMEs and Lane (2023) for a justification for setting α to -0.3.

[39] We abstract from any general equilibrium effects in both scenarios and instead focus on tracing out the cyclical income implications of the two alternative balance sheet scenarios.

[40] The assumption on the exact adjustment of liability items to offset the change in asset holdings in both scenarios is not trivial, as the ECB balance sheet can be seen as an equilibrium outcome in which financial institutions and economic agents can flexibly determine their optimal portfolio holdings.

Figure 5: Projected and counterfactual interest and inflation rate paths



Notes: Model simulations for counterfactual interest and inflation rate paths based on Equation 10. Latest observations: 2030 (projected).

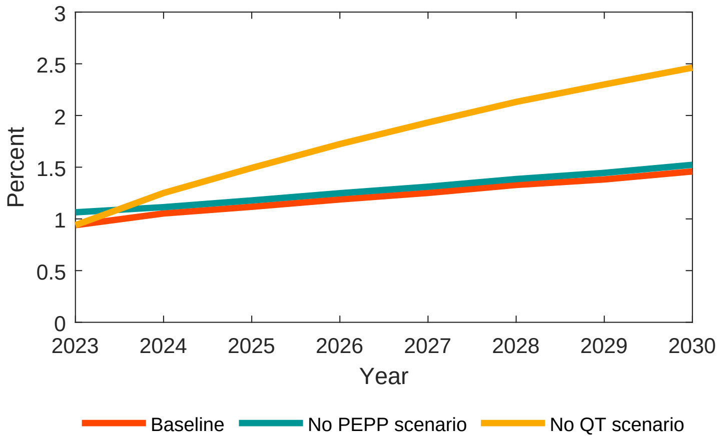
the baseline because of the fact that autonomous factors grow over time.[41] As for the baseline scenario, we assume that the ECB fills any resulting liquidity deficit with refinancing operations remunerared at the MRO rate. By contrast, in the no-QT scenario, the expansion of the ECB balance sheet that is eventually required by the growth of autonomous factors, is postponed beyond our projection period.

Second, the average annual returns r_t^b earned on the bond portfolio also vary under both balance sheet scenarios. For the no-PEPP scenario, we adjust the returns by excluding the PEPP holdings from the r_t^b calculations as detailed in Section 3, leading to a modest increase in bond returns since market yields were on average lower during the PEPP purchase phase from 2020 onward (green line Figure 6). The no-QT scenario requires an explicit assumption about the yields on reinvested securities throughout the simulation horizon. We assume that, starting in 2023, a constant share of the portfolio is rolled over annually.[42] Maturing securities are reinvested in government bonds with a 10-year maturity at the time of reinvestment,

[41] Autonomous factors refer to items on a central bank's balance sheet unrelated to monetary policy operations or reserve holdings and thus not directly under the central bank's control, such as net government deposits, banknotes in circulation, or net foreign assets. See e.g. Bindseil (2014).

[42] We set this share at 11 percent, which reflects the average redemption rate of the APP portfolio since the ECB terminated its reinvestments.

Figure 6: Projected bond portfolio returns



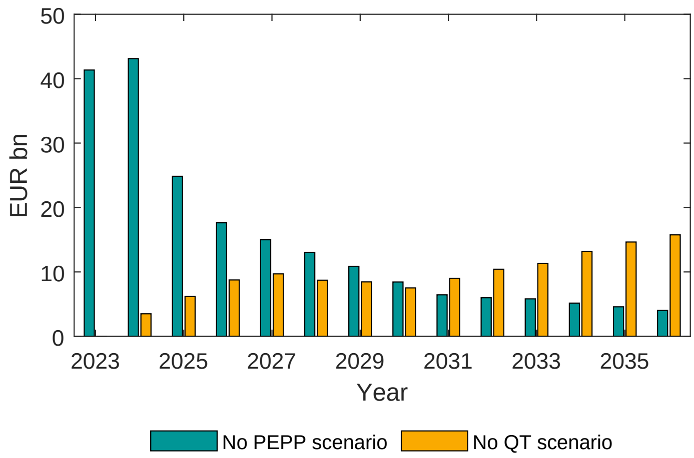
Notes: Average returns r_t^b earned on portfolio holdings B_t, computed as outlined in Section 3. no-PEPP and no-QT scenario returns as applied in simulations in Figure 7. 10y forward sovereign bond yield given by forward curve as of end-2023. Latest observations: 2030 (projected).

with forward yields derived from the spot curve as of December 2023.[43] The continuation of reinvestments of principal payments from maturing securities into 10-year bonds increasingly boosts the portfolio return over time as lower-yield securities are gradually reinvested at higher yields (yellow line Figure 6).

The impact on ECB income in both scenarios is reported in Figure 7. The simulations indicate that both counterfactual scenarios yield an improvement in cumulative ECB income throughout the projection horizon. Specifically, the no-PEPP scenario (green bars Figure 7) reveals that the asset purchases conducted under the PEPP prior to the start of the hiking cycle amplify the cyclicality of ECB income. Our income model predicts that excluding securities purchased under PEPP from the portfolio would result in cumulative ECB losses that are substantially lower, especially in the near term. For instance, over 2023 and 2024, losses would cumulate to only €29bn, and would thus turn out approximately 75 percent lower than projected in Figure 4 (cumulative €113bn in 2023 and 2024, implying an improvement of €84bn in the net income position in absolute terms in the two years). At the same time, income from PEPP securities would have been over €10bn lower

[43]This assumption implies that the portfolio composition effect, associated with the earlier exit of bonds from the portfolio with shorter maturities, is limited to legacy holdings and does not affect holdings from future reinvestments.

Figure 7: Change in ECB net income paths under alternative balance sheet scenarios



Notes: Model simulations for ECB net income based on Equation 1. No-PEPP and no-QT scenarios as deviations from baseline in Figure 4. Latest observations: 2036 (projected).

during the 2020-2022 period.[44] The income-enhancing effects in this scenario are primarily driven by a reduced balance sheet size, which leads to a lower volume of negative carry securities, while the average yield on the portfolio experiences only a modest increase throughout the projection horizon.

Our second scenario indicates that anticipated ECB income would be higher throughout the projection horizon if the ECB did not engage in quantitative tightening, and instead continued to reinvest principal payments from maturing securities in its QE portfolios (yellow bars in Figure 7). While the immediate gains are more pronounced under the no-PEPP scenario, the benefits of continuing reinvestments for ECB income become particularly evident later in the decade. This shift occurs as lower-yielding securities are gradually replaced with higher-yielding bonds. Quantitatively, the scenario suggests that accumulated losses would therefore be marginally reduced by approximately 4 percent during the 2023-2024 period when compared to the baseline. However, the long-term income effect appears significantly more

[44]This estimate is derived from the interest income reported in the annual reports of NCBs, some of which detail income by portfolio. For example, the ECB, Bundesbank, Banco de España, and Banca d'Italia – collectively holding around 59 percent of PEPP securities at the end of 2023 –accrued a total of €7.7bn in interest income from the PEPP between 2020 and 2023.

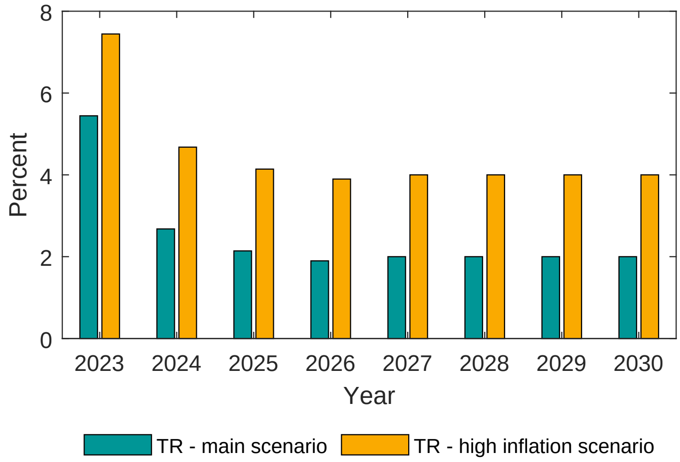
pronounced, with projected cumulative profits surging by 46 percent for the years 2027-2030 relative to the baseline scenario.

The improvements in profitability in both alternative balance sheet scenarios compared to the baseline scenario are reflected in a relatively benign need to account for losses under a zero-loss policy. Consequently, the near-term zero-loss interest rate and inflation paths in the no-PEPP and no-QT scenarios deviate less from the paths prescribed by the baseline scenario (green triangles and yellow diamonds compared to red bars in Figure 5). In the no-PEPP scenario for which the near-term improvements in income are largest (green bars in Figure 7), the policy rate would have to be set at 2.4 percent in 2023 and 2.9 percent in 2024, before returning to the same levels as in the baseline scenario from 2025 onwards. In turn, inflation differentials between the no-PEPP and the baseline scenario are smallest, with the inflation gap standing at 24 and 22 basis points in 2023 and 2024, respectively, before being fully closed from 2025 onwards. In the no-QT scenario, positive income effects unfold mainly over the medium term (yellow bars in Figure 7), such that the near-term trajectories for interest rates and inflation turn out closer to the trajectories under a zero-loss policy followed in the baseline scenario (grey dots in Figure 5). Interest rates would be set at 1.7 percent in 2023, 2.1 percent in 2024, 2.4 percent in 2025, and 2.5 percent in 2026. In turn, inflation gaps in the no-QT scenario with a zero-loss policy would be very similar to the gaps resulting from a zero-loss policy if pursued in the baseline scenario.

4.2.2 Ex-ante loss reporting ability and monetary policy

The above analysis implies that a central bank primarily concerned with its financial results may be forced to accept higher inflation rates once it is confronted with losses. Inverting this logic, we show that a central bank pursuing a price stability mandate may be required to tolerate losses *ex ante* when being confronted with an unexpected inflation shock. To show this, we assume that the central bank sets interest rates taking into account inflation and economic activity, following a Taylor (1993)-type monetary policy reaction function. Specifically, we use this policy rule to derive alternative paths for the nominal short-term interest rate i_t under two scenarios: a "main" scenario characterized by the ECB's 2023 December projections, and an alternative "high-inflation" scenario in which inflation is projected to remain two

Figure 8: Scenario HICP inflation paths



Notes: HICP inflation rates for the main scenario (ECB 2023 December projections) and the alternative high-inflation scenario. Latest observations: 2030 (projected).

percentage points above the inflation trajectory in the main scenario every year (Figure 8).[45]

The resulting paths for i_t are obtained employing a Taylor (1993)-type rule as in Coenen et al. (2019):

$$\hat{i}_t = \rho_i \hat{i}_{t-1} + (1-\rho_i)\big[\rho_r + \phi_\pi \hat{\pi}_t + \phi_y \hat{y}_t + \phi_{\Delta\pi}(\hat{\pi}_t - \hat{\pi}_{t-1}) + \phi_{\Delta y}(\hat{y}_t - \hat{y}_{t-1})\big], \quad (13)$$

with $\hat{i}_t = \log(i_t/\bar{i})$ describing the logarithmic deviation of the short-term nominal interest rate from its long-run level, $\hat{\pi}_t = \log(\pi_t/\overline{\pi})$ being the logarithmic deviation of the inflation rate from the central bank's long-run inflation objective $\overline{\pi}$, and $\hat{y}_t$ referring to the output gap. As in Coenen et al. (2019), we augment the policy rule with a term describing the perceived permanent component of productivity growth, ρ_r.[46] We calibrate all rule parameters and long-term values following Coenen et al.

[45]The stylized high-inflation scenario features an ad-hoc upward revision of the HICP path compared to the 2023 December projections, while keeping all other inputs to the interest rate rule 13 unchanged from the baseline scenario.

[46]Coenen et al. (2019) include a comparable term for the estimated persistent component of the permanent technology shock to the Taylor (1993)-type interest rate rule in the New Area-Wide Model II. In doing so, they account for the slowing of productivity growth over the past decades in the euro area. Excluding this term from Equation 13 yields a somewhat lower level of nominal short-

(2019), except for the interest rate smoothing parameter ρ_i which is set to a quarter of the original value due to the annual frequency of our analysis and the central bank's inflation objective which we set to 2 percent (Table 3).

Table 3: Calibration Taylor (1993)-type monetary policy rule

Parameter	Description	Value
ρ_i	Interest rate smoothing	0.2325
ϕ_π	Inflation response	2.74
ϕ_y	Output gap response	0.03
$\phi_{\Delta\pi}$	Inflation change response	0.04
$\phi_{\Delta y}$	Output gap change response	0.1
ρ_r	Productivity growth component	0.94
$\overline{\pi}$	Inflation objective (%)	2
$\bar{i}$	Long-run nominal interest rate (%)	4

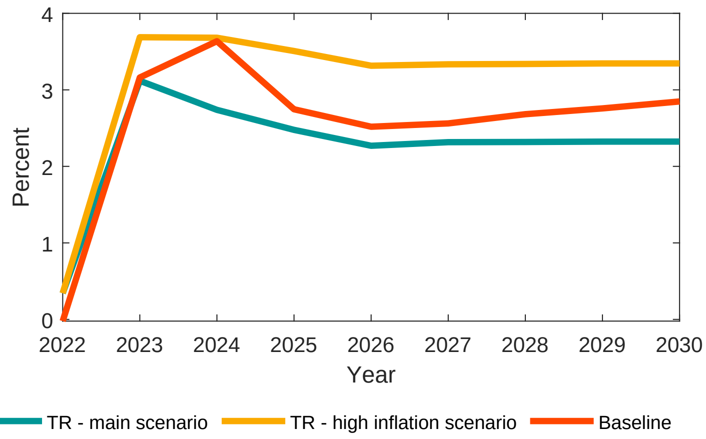
Feeding the paths for inflation and the output gap[47] for both the main and the alternative high-inflation scenarios in the interest rate rule 13 yields the scenario paths for the short-term nominal interest rate depicted in Figure 9. The hypothetical policy paths implied by the Taylor (1993)-type rule (green and yellow lines in Figure 9) are reasonably close to the nominal €STR path – serving as our policy rate proxy in Section 4.2.1 – in the ECB 2023 December projections (red line in Figure 9). The higher inflation path in the alternative scenario translates, via policy rule 13, into a higher path of the short-term nominal interest rates, with the spreads over the main scenario ranging between 0.6 and 1.0 ppt. per year over the 2023-2030 period (Figure 10).

Simulating the income model of Section 3.1 for the two scenarios shows that a tighter policy stance – reflected in a higher interest rate path due to the higher path of inflation – compared to the main scenario potentially reduces central bank profitability: The deferred asset holdings obtained in the high-inflation scenario (yellow bars Figure 11) are significantly larger than those obtained in the main

term rates, leaving the dynamic profiles and absolute spreads between scenarios unchanged. While the original Taylor (1993)-type rule in Coenen et al. (2019) included an additional term capturing deviations of the period-t inflation rate from a time-varying inflation objective, we assume a time-invariant objective for simplicity, which is also consistent with the 2-percent inflation objective the ECB adopted following its strategy review.

[47]ECB December 2023 projections for HICP inflation. As ECB output gap estimates are not publicly available, we use euro area output gap projections as published in the European Commission's Autumn 2023 Economic Forecast. The data can be found here.

Figure 9: Nominal interest rate paths

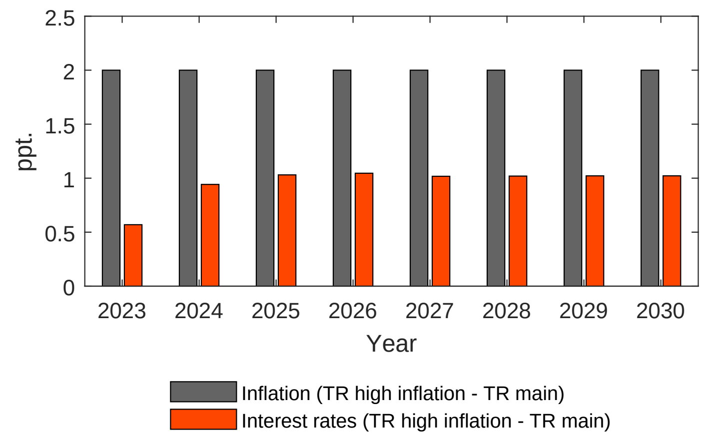


Notes: Nominal short-term interest rates (in percent) for the Taylor-rule baseline scenario (ECB December projections for inflation and European Commission Autumn 2023 Economic Forecast output gap fed in) and the alternative Taylor-rule high-inflation scenario (high-inflation path and European Commission Autumn 2023 Economic Forecast output gap fed in). The baseline €STR path (red) refers to the ECB December 2023 projections. Latest observations: 2030 (projected).

scenario (green bars Figure 11).[48] Mirroring the rate path in Figure 9, the deferred asset path obtained from the baseline income projection shown in Figure 4 (red bars Figure 11) falls within the high- and low-inflation scenarios obtained with policy rule 13.

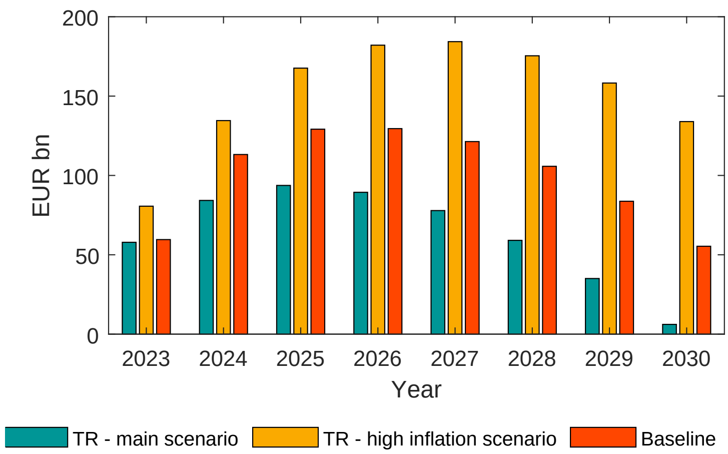
[48]The relative size of the deferred assets in both scenarios are ultimately determined jointly by the specific design of the dividend rule 1, the specification of the Taylor (1993)-type policy reaction function 13, and the assumed inflation path in the alternative scenario.

Figure 10: Differences in interest and inflation rates



Notes: "TR - main" referring to Taylor-rule baseline scenario (ECB December projections for inflation and European Commission Autumn 2023 Economic Forecast output gap fed in), "TR - high inflation" referring to alternative Taylor-rule high-inflation scenario (high-inflation path and European Commission Autumn 2023 Economic Forecast output gap fed in).

Figure 11: Differences in deferred asset



Notes: "TR - main scenario" referring to Taylor-rule baseline scenario (ECB December projections for inflation and European Commission Autumn 2023 Economic Forecast output gap fed in), "TR - high inflation scenario" referring to alternative Taylor-rule high-inflation scenario (high-inflation path and European Commission Autumn 2023 Economic Forecast output gap fed in). "Baseline" referring to the deferred asset obtained from the main income projection derived in Section 4.2.1, Figure 4. Model simulations for deferred asset based on Equation 3.

While the largest deferred asset holdings are projected for 2025 in the main Taylor (1993)-rule scenario (green bars) and for 2026 in the baseline net income projections (red bars), peak holdings are only reached in 2027 in the case of the high-inflation scenario (yellow bars). At the peak, the deferred asset holdings in the high-inflation scenario are more than twice as large as in the main Taylor-rule scenario (50 percent larger than the holdings derived from the baseline income projection in Figure 4). In all cases, holdings are projected to gradually decline over the final years of the decade. In none of the cases, the deferred asset is fully depleted by 2030, with holdings in the high-inflation scenario still totalling €144bn in 2030 compared to more benign levels in the other two scenarios (€67bn in the baseline income projection and €17bn in the main Taylor-rule scenario, respectively). The simulations therefore show that the ability to post negative income – and the ability to potentially account for temporary losses in deferred asset holdings – is a precondition, rather than obstacle, for the pursuit of an inflation target. The ability to set interest rates in line with the monetary policy stance may require temporarily accepting its adverse impact on the central bank's profitability.

5 Conclusion

The significant tightening of interest rates by central banks across the world following a decade of expansive balance sheet policies has negative implications for their income. The analysis in this paper examines the conditions under which a decline in central bank profitability could negatively impact price stability.

Modelling the ECB's profits using publicly accessible data reveals that expansive balance sheet policies introduce a cyclical element into the central bank's profitability. At the same time, our analysis suggests that the current dip in profitability, brought about by rising interest rates, does not undermine the fundamental financial strength of the Eurosystem. This is due to the increased net present value of future seigniorage income, which acts as a natural hedge against interest rate risk.

Furthermore, we explore the consequences of temporary financial losses on inflation outcomes. In particular, we study the inflationary consequences of a zero-loss strategy by establishing a systematic relationship between net income and hypothetical scenarios of short-term interest and inflation rates. These scenarios are constructed to ensure a consistent flow of non-negative income over time, utilizing the approach outlined in the Hall and Reis (2015) dividend model. Our results suggest that if the ECB were to adopt a "zero-loss" strategy, it would need to implement a significantly lower interest rate path compared to the assumptions underlying the ECB's December 2023 projections. We show that this decrease in policy rates to avoid losses over the next years would likely result in an increase in inflation. Conversely, an unexpected upward shock to inflation would require a monetary policy reaction which would lead to additional losses to be accounted for on the central bank's balance sheet. We therefore conclude that the ability to offset temporarily negative income through risk provisioning or withholding dividend payments should be seen as an expression of a central bank's financial independence, and constitutes a prerequisite to successfully controlling inflation.

References

Adrian, T., Erceg, C., Kolasa, M., Lindé, J., McLeod, R., Veyrune, R., and Zabczyk, P. (2024). New Perspectives on Quantitative Easing and Central Bank Capital Policies. *IMF Working Paper Series*, (24/103).

Belhocine, N., Bhatia, A. V., and Frie, J. (2023). Raising Rates with a Large Balance Sheet: The Eurosystem's Net Income and its Fiscal Implications. *IMF Working Paper Series*, (2023/145).

Benecká, S., Holub, T., Kadlčáková, N. L., and Kubicová, I. (2012). Does Central Bank Financial Strength Matter for Inflation? An Empirical Analysis. *CNB Working Paper Series*, (2012/3).

Bindseil, U. (2014). *Monetary Policy Operations and the Financial System*. OUP Oxford.

Bindseil, U., Manzanares, A., and Weller, B. (2004). The Role of Central Bank Capital Revisited. *ECB Working Paper Series*, (392).

Brand, C., Lisack, N., and Mazelis, F. (2024). Estimates of the Natural Interest Rate for the Euro Area: An Update. *ECB Economic Bulletin*, 1/2024.

Buiter, W. H. (2024). Central Banks Need to Be Honest About Their Losses. Project Syndicate commentary. Available here.

Cecchetti, S. G. and Hilscher, J. (2024). Fiscal Consequences of Central Bank Losses. *NBER Working Paper Series*, (32478).

Coenen, G., Karadi, P., Schmidt, S., and Warne, A. (2019). The New Area-Wide Model II: An Extended Version of the ECB's Micro-Founded Model for Forecasting and Policy Analysis with a Financial Sector. *ECB Working Paper Series*, (2200).

Corsetti, G. and Dedola, L. (2016). The Mystery of the Printing Press: Monetary Policy and Self-Fulfilling Debt Crises. *Journal of the European Economic Association*, 14(6):1329–1371.

De Grauwe, P. and Ji, Y. (2023). Monetary policies with fewer subsidies for banks: A two-tier system of minimum reserve requirements. VOXEU blog entry. Available here.

Del Negro, M. and Sims, C. A. (2015). When Does a Central Bank's Balance Sheet Require Fiscal Support? *Journal of Monetary Economics*, 73:1 – 19.

ECB (2016). A Guide to the Eurosystem/ECB Staff Macroeconomic Projection Exercises. *ECB Staff Project Guide*.

ECB (2022). The use of the eurosystem's monetary policy instruments and its monetary policy implementation framework in 2020 and 2021. *Occasional Paper No. 304*.

Fornaro, L. and Grosse-Steffen, C. (2024). Fragmented Monetary Unions. *BSE Working Paper Series*, (1437).

Goncharov, I., Ioannidou, V., and Schmalz, M. C. (2021). (Why) Do Central Banks Care about Their Profits? *Journal of Finance*, (forthcoming).

Hall, R. E. and Reis, R. (2015). Maintaining Central-Bank Financial Stability under New-Style Central Banking. *NBER Working Paper Series*, (21173).

Ize, A. (2005). Capitalizing Central Banks: A Net Worth Approach. *IMF Staff Papers*, 52(2):289–310.

Krugman, P. (2011). The Printing Press Mystery. The Conscience of a Liberal blog entry. Available here.

Lane, P. R. (2023). The Euro Area Hiking Cycle: An Interim Assessment. Dow Lecture by Philip R. Lane, Member of the Executive Board of the ECB, at the National Institute of Economic and Social Research. Available here.

Long, J. and Fisher, P. (2024). Central Bank Profit Distribution and Recapitalisation. *Bank of England Staff Working Paper*, (1069).

Perera, A., Ralston, D., and Wickramanayake, J. (2013). Central Bank Financial Strength and Inflation: Is there a Robust Link? *Journal of Financial Stability*, 9(3):399 – 414.

Pinter, J. (2008). Does Central Bank Financial Strength Really Matter for Inflation? The Key Role of the Fiscal Support. *Open Economies Review*, 29(5):911 – 952.

Reis, R. (2013). The Mystique Surrounding the Central Bank's Balance Sheet, Applied to the European Crisis. *American Economic Review*, 103(3):135 – 140.

Reis, R. (2015). Different Types of Central Bank Insolvency and the Central Role of Seignorage. *NBER Working Paper Series*, (21226).

Stella, P. (1997). Do Central Banks Need Capital? *IMF Working Paper Series*, (1997/083).

Stella, P. (2008). Central Bank Financial Strength, Policy Constraints and Inflation. *IMF Working Paper Series*, (2008/049).

Taylor, J. B. (1993). Discretion versus Policy Rules in Practice. *Carnegie-Rochester Conference Series on Public Policy*, 39:195–214.

Wang, X. and Zwinkels, R. C. J. (2024). Breaking the Trilemma: Seigniorage, Endogenous Remittances, and Digital Currency. *Available here*.

6 Model Appendix

6.1 The marginal impact of rate changes on net worth

First, substituting Equation 1 in Equation 7 gives:

$$NW_t = \sum_{k=0}^{\infty} \mathbb{E}_t \left\{ \frac{r^b_{t+k} B_{t+k} + i_{t+k}(A_{t+k} - L_{t+k}) - i^*_t (A^n_{t+k} - L^n_{t+k})}{\prod_{\tau=0}^{k}(1 + i_{t+\tau})} \right\}, \tag{14}$$

where P_{t+k} cancels out, yielding the net worth of the central bank in nominal terms. Taking a partial derivative w.r.t. i_{t+k} yields

$$\begin{aligned} \frac{\partial NW_t}{\partial i_{t+k}} =& \frac{(A_{t+k} - L_{t+k}) \prod_{\tau=0}^{k}(1 + i_{t+\tau})}{\left(\prod_{\tau=0}^{k}(1 + i_{t+\tau})\right)^2} - \\ & \frac{\prod_{\tau=0}^{k-1}(1 + i_{t+\tau})(r^b_{t+k} B_{t+k} + i_{t+k}(A_{t+k} - L_{t+k}) - i^*_t (A^n_{t+k} - L^n_{t+k}))}{\left(\prod_{\tau=0}^{k}(1 + i_{t+\tau})\right)^2}, \end{aligned} \tag{15}$$

where we used that the derivative of $\prod_{\tau=0}^{k}(1+i_{t+\tau})$ w.r.t. i_{t+k} equals $\prod_{\tau=0}^{k-1}(1+i_{t+\tau})$. Setting successively $i^*_t = 0$ and $B_{t+k} = 0$ and collecting terms:

$$\frac{\partial NW_t}{\partial i_{t+k}} = \frac{(A_{t+k} - L_{t+k}) \prod_{\tau=0}^{k}(1 + i_{t+\tau}) - \prod_{\tau=0}^{k-1}(1 + i_{t+\tau})(i_{t+k}(A_{t+k} - L_{t+k}))}{\left(\prod_{\tau=0}^{k}(1 + i_{t+\tau})\right)^2}, \tag{16}$$

$$= \frac{\prod_{\tau=0}^{k-1}(1 + i_{t+\tau})(A_{t+k} - L_{t+k})[(1 + i_{t+k}) - i_{t+k}]}{\left(\prod_{\tau=0}^{k}(1 + i_{t+\tau})\right)^2} \tag{17}$$

$$= \frac{A_{t+k} - L_{t+k}}{(1 + i_{t+k}) \prod_{\tau=0}^{k}(1 + i_{t+\tau})}, \tag{18}$$

where we used that $\prod_{\tau=0}^{k}(1 + i_{t+\tau}) = \prod_{\tau=0}^{k-1}(1 + i_{t+\tau})(1 + i_{t+k})$ from the first to the second line and $\frac{\prod_{\tau=0}^{k-1}(1+i_{t+\tau})}{\prod_{\tau=0}^{k}(1+i_{t+\tau})} = \frac{1}{1+i_{t+k}}$ from the second to the third line. Notably, with a bond portfolio $B_{t+k} \neq 0$, Equation 18 becomes:

$$\frac{\partial NW_t}{\partial i_{t+k}} = \frac{A_{t+k} - L_{t+k} - r^b_{t+k} B_{t+k}}{(1 + i_{t+k}) \prod_{\tau=0}^{k}(1 + i_{t+\tau})}. \tag{19}$$

Equation 19 suggests that the effect of future policy rate increases on the overall net worth of a central bank can be negative when the central bank holds a bond portfolio and $A_{t+k} < L_{t+k} + r^b_{t+k} B_{t+k}$.

6.2 The market value of the Eurosystem bond portfolio

The European Central Bank (ECB) reported a contraction in the market valuation of its bond portfolio exceeding 15 percent (from €453bn at the end of 2021 to €385bn by the end of 2023). To evaluate the accuracy of our model in reflecting these market dynamics, we compare the official data with a simplified revaluation methodology based on the net present value of the expected future cash flows from the portfolio. In particular, the price of the bond can be represented by:

$$q_t = \mathbb{E}_t \left\{ \sum_{k=0}^{m} \frac{r_t^b B_t}{\prod_{\tau=0}^{k}(1+i_{t+\tau})} + \frac{B_t}{\prod_{\tau=0}^{m}(1+i_{t+\tau})} \right\}. \tag{20}$$

We set the average coupon $r_t^b = 1.46$ percent, calculated in accordance with the methodology specified in Section 3.2. Furthermore, the average maturity of the portfolio is set at $m = 7$ years. We then compare the price q_t based on the €STR forward curve prevailing in December 2021 and 2023. Our findings indicate that the price of the average bond in the portfolio depreciated by approximately 18 percent, which aligns closely with the figures disclosed by the ECB.

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