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On the capitalisation of central banks

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Authors: Paul Wessels and Dirk Broeders[1]

Abstract

In contrast to commercial banks, there are no rules or clear guidelines for central banks' capital adequacy. Although central banks cannot default as long as they have the right to issue legal tender, capital adequacy is important to be a credible, independent monetary authority over a medium-term horizon. Central banks face several challenges in determining their capital adequacy. First, the amount of capital only plays an auxiliary role in central banks' effectiveness. Second, central banks face "latent risks" in addition to the regular calculable financial risks. These latent risks are difficult to quantify because they stem from contingent policy measures such as quantitative easing and lending of last resort. Latent risks are related to GDP and the size of the financial sector in the economy. We argue that a central bank's target level of capital (1) can be calibrated with a confidence level that is lower than that used for commercial banks and (2) is proportional to for instance GDP as a proxy for the latent risks. We propose a set of guidelines to arrive at such a central bank capital policy. Capital adequacy will get significant attention over the coming years as many central banks have to draw on their buffers following rising interest rates in response to higher inflation.

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Contents

1 Introduction

In many ways, central banks resemble commercial banks. Deposit-taking and lending are common operations for central banks, just as they are for commercial banks. When conducting these operations, both types of banks use their balance sheet to perform a number of economic functions such as credit, maturity and size transformation. In addition, both are highly leveraged, with leverage being defined as the ratio of total assets to available capital. There are also a number of differences. For example, central banks fulfil the important public tasks of designing and implementing monetary policy and maintaining financial stability. That is why in many cases the State is the central bank's single shareholder, whereas a large base of private and institutional investors are the owners of commercial banks.[2] With their control over the currency, central banks cannot default, whereas commercial banks can. Furthermore, in times of crisis, when trust in commercial banks declines and these banks may choose to reduce their risk profiles, central banks absorb risks from the financial system in order to restore confidence.

For both commercial banks and central banks, capital plays a key role in risk management. Capital is defined as shareholder equity available for absorbing losses and typically consists of statutory capital plus retained earnings and other provisions or reserves with unlimited loss-absorbing capacity.[3]

2 Some central banks also have private shareholders. For historical reasons the central banks of Belgium, Japan, Greece, Switzerland and South Africa are publicly traded on a stock exchange. Furthermore, in times of crisis a State may choose to nationalise a commercial bank in whole or in part for financial stability reasons. In such an event the State becomes the shareholder of a commercial bank.

3 Adequate accounting standards and appropriate legal clauses regarding interactions with government are crucial to assess the level of capital from an economic perspective.

Similarly, available capital is defined as the value of total assets minus the value of total liabilities.

For commercial banks, capital is a buffer to absorb losses. Commercial banks are highly regulated and the "Basel regulations" largely concern the minimum level of capital vis-à-vis the bank's risk exposures. There is a general consensus that an adequate level of capital is necessary to protect the claims that bond and deposit holders have on a commercial bank with a high degree of certainty. Additionally there are positive macroeconomic benefits of banking regulation in reducing the probability and costs of future banking crises. In banking regulation, the actual exposures on a commercial bank's balance sheet serve as a basis for determining the minimum required level of capital. Regulatory requirements do not anticipate future changes in risk exposures.[4] If necessary, a commercial bank can stop new lending activities or even reduce exposures to protect its capital. Extensive literature is devoted to the consequences of commercial banks' capitalisation. See, for example, BCBS (2019) for a literature review of the costs and benefits of bank capital.

For central banks, capital also acts as a buffer to absorb risks. However, central banks are not subject to capital regulations and there is much less consensus on the minimum amount of capital that is considered adequate. By construction, there is only one central bank in each jurisdiction, and the preconditions under which the central bank operates are usually based on specific goals, national laws

4 Macroprudential requirements such as systemic buffers are not necessarily based only on the actual exposures. Size, interconnectedness and complexity also play a role in these macroprudential requirements.

and practices that are reflected in its statutes. Many central banks focus on price stability or on price stability and employment, but other primary or secondary objectives are also possible, such as exchange rate stability and financial stability. This creates diversity amongst central banks and makes it less clear how much capital is considered adequate. In addition, the risks on a central bank's balance sheet are more contingent on the state of the economy than in the case of commercial banks. In a severe economic downturn a central bank may swiftly increase its balance sheet and, by doing so, absorb additional risks. This makes it challenging to calibrate a minimum capital level. Yet in anticipation of such an event, a central bank may want to have ample capital, because during a severe economic downturn it will be challenging to increase capital. Conversely, there are also reasons why a low amount of capital may be considered sufficient. First, a central bank enjoys implicit government support as a systemically vital national authority. Second, a central bank can create money and therefore cannot default on its own currency, so there is no discontinuity risk as in the case of commercial banks.

1.1 Our contribution

Our primary contribution concerning central bank capital adequacy with this paper is threefold:

- We follow a strict financial risk management approach to central bank capital adequacy. By exploring the differences between central banks and commercial banks, we propose a capital adequacy for central banks that can be based on a confidence level that is lower than the 99.9% used in solvency regulation for commercial banks.

- We analyse the latent risks that central banks are exposed to and propose a method to quantify their order of magnitude vis-à-vis macroeconomic parameters such as GDP or the size of the financial sector. The inability to assess these latent risks accurately and the auxiliary role of capital for the purpose of independence suggest that it is acceptable to base capital adequacy on a heuristic in relation to these macroeconomic parameters.
- We propose guidelines that are applicable to different types of central banks. The idiosyncratic characteristics of a central bank appear in the analysis of the latent risks translating into the heuristic for determining capital adequacy. A few additional rules regarding the distribution of profits between the central bank and the government can ensure that the actual capitalisation tends towards the target fast enough most of the time.

In addition, this paper puts forward a few secondary contributions. First, we present a nuanced view on central bank independence. Independence is often discussed as a binary concept: either the central bank is independent from the government or it is not. In practice, central bank independence is more nuanced and connected to a time horizon. For instance, a central bank is only independent over the short- to medium-term horizon, say five up to ten years. Beyond this time horizon, the central bank is not independent, as it is subject to democratic authorities controlling legislation, i.e. the government and parliament. Second, we argue that the central bank is entitled to earn a fair profit margin on its monetary policy implementation because this provides a key service to the economy.[5] Third, we argue that central bank accounting standards can be similar

5 Note that the benefits of a well-function central bank to society is much larger than its profit margin only.

to those of private sector firms with one exception: the right to build up a general reserve fund. This fund gives the central bank more discretionary control over its dividend payments. With this fund, the central bank has more control over its buffer growth and is less likely to require capital injections from the government.

1.2 Overview of the literature

Because central banks are diverse and not regulated, literature on the topic of central bank capital adequacy is only available to a limited extent. However, as central bank profits can be sizeable and constitute a non-negligible part of the government budget, the topic of central bank capitalisation is relevant. A paper by Stella (1997) triggered a series of papers from the IMF staff and others, in particular Blejer and Schumacher (1998), Stella (2002), Ize (2005), Stella and Lonnberg (2008), Klüh and Stella (2008) and Adler, Castro and Tovar (2012). The main conclusion from these papers is that financial strength is key for a central bank to be independent from governments and to be credible in achieving its policy objectives. According to Stella (1997) and later papers, the notion of financial strength focusses on the net worth of the central bank, including the franchise value (or seigniorage) as well as its off-balance sheet rights and obligations.[6] The monopoly in the provision of the domestic currency gives the central bank a significant franchise value. Furthermore, central banks can create demand for their own liabilities by imposing reserve requirements on banks. The target level of capital according to Stella (1997) should be dependent on the

6 Seigniorage income is derived from the difference in interest rate on the assets and the interest rate on liabilities. The latter is zero in the case of banknotes.

precise policy objectives. Furthermore, Stella (1997) lists four ways to express a target level of capital: (1) an absolute level, (2) a target ratio relative to another balance sheet item, (3) a target level relative to a macroeconomic variable, and (4) in relation to the central bank's perceived risks. The ultimate risk for a central bank is "policy insolvency", i.e. that it is not able to meet its policy commitments. The ultimate risk for a central bank is not the more common technical insolvency, or the inability to meet its financial liabilities.

Blejer and Schumacher (1998) are among the first to take a strict risk management approach to central bank solvency using the well-known Value-at-Risk (VaR) methodology. They postulate that central banks with a high overall VaR face limited effectiveness. Other papers from Ernhagen, Vesterlund and Viotti (2002), Martínez-Resano (2004) and Bindseil, Manzanares and Weller (2004) also present perspectives on central bank capital adequacy using quantitative models. Erhagen, Vesterlund and Viotti (2002) estimate the capital needed as the central bank's operational costs plus potential foreign exchange rate losses in a stress scenario. Martínez-Resano (2004) analyses a central bank's risks and develops a Basel-like formula for financial strength. An important consideration in capital adequacy is a central bank's franchise value. Bindseil, Manzanares and Weller (2004) conclude that a negative capital position of a central bank will generally be restored by future profits, except in two specific scenarios: an economic deflationary trap and a scenario with extremely low growth in banknotes. Buiter (2008) argues along the same lines as Bindseil, Manzanares and Weller (2004) that central banks can go broke but stresses that it is the comprehensive net worth of the central bank that matters. This comprehensive net worth includes future seigniorage income. He also places less

emphasis on capital adequacy, as ultimately the Treasury should stand ready to recapitalise the central bank.

An important contribution to the topic of central bank capital adequacy is the BIS Paper by Archer and Moser-Boehm (2013). It gives a rich overview of the theoretical and empirical literature as well as the practices in the central banking community. The authors take a broad perspective on a central bank's financial strength, including balance sheet composition, income generation and accounting rules, as well as the capital buffers on the balance sheet. They conclude that the central banking community is so heterogeneous that the question of capital adequacy is highly idiosyncratic. The framework they present for assessing the appropriate amount of financial strength is therefore also broad. The capital that is ultimately needed depends on the specific policy responsibilities of the central bank, the amount of risk that cannot be transferred to the government and the accounting policies and the profit distribution scheme in place. A profit distribution scheme specifies which part of the profits is retained and which part is transferred to the State in the form of dividend.

Capital adequacy is key to being a credible, independent monetary authority. The topic of central bank independence has received quite a lot of attention over the years. Good overviews are provided, for instance, by Berger, de Haan and Eijffinger (2001) and de Haan and Eijffinger (2019). Today, central bank independence is mostly accepted as a necessary requirement for an effective central bank responsible for monetary policy (Blinder, 1998), although some criticism also exists (Draghi, 2018). In the Eurosystem, the concept of central bank independence is operationalised in the ECB convergence reports, see e.g. ECB

(2020). These convergence reports describe four dimensions of independence: functional, institutional, personal and financial. According to these reports, financial independence includes sufficient capitalisation. Cukierman (2011) sets out a number of considerations with regard to the level of central bank capital needed to safeguard independence in scenarios where risks and losses accumulate. Key determinants of central bank capital according to the author are: the size of potential shocks, the breadth of responsibilities, the tendency of governments to create deficits, the institutional arrangement between the central bank and the government, the structure of the central bank's balance sheet and the central bank's credibility. A number of Cukierman's conclusions are in line with our paper, but on a more generic level.

2 The role of the central bank in the economy

Central banks are national authorities with a specific mandate, see e.g. Mishkin (2019). Under their mandate they typically perform a number of tasks such as issuing fiat money, organising a safe and secure payment infrastructure, designing and implementing monetary policy and acting as a lender of last resort by offering loans to commercial banks that otherwise have no means of borrowing, and whose failure would adversely affect the economy. Often central banks also manage part of the national reserves and hold significant amounts of securities denominated in foreign currency for the purpose of monetary policy interventions. For the commercial banking sector, the central bank acts as a bank, i.e. commercial banks hold deposits at the central bank to facilitate interbank transactions. Commercial banks can also obtain financing from the central bank, which typically ranges from regular credit operations at near-market competitive rates to special credit windows with more onerous terms, such as those defined under the lender of last resort function.

In their capacity as "banks for commercial banks", central banks run many of the typical financial risks that commercial banks also face. Credit risks result from the credit operations through which a central bank lends money to a commercial bank on the basis of adequate collateral. Market risk originates from holding foreign currency securities and asset purchase programmes, while the exposure to interest rate risk comes from the mismatch between the duration of assets and liabilities. In recent years, the balance sheets of numerous central banks have grown substantially as a consequence of crisis-related measures and quantitative

easing (QE) policies, adding to the credit, market and interest rate risks they run.[7] Only liquidity risk is typically not a concern for central banks. With their control of the domestic currency and the absence of liabilities in foreign currency, central banks do not end up in a situation where they cannot meet the necessary payments when they are due.

In fulfilling their mandates, central banks make profits on the services that they provide to society and to commercial banks. A central bank is the monopoly supplier of banknotes that the general public uses as legal tender in day-to-day life. By acting as the bank for commercial banks, the central bank performs economic transformations and takes over risks from the banking sector. As the central bank can set the terms and conditions, both these functions contribute in general to the central bank's profitability. The benefit of profitability is that it increases a central bank's independence from government and contributes to a positive perception on the part of the general public that the central bank is a "revenue centre". The flipside of this is that unexpected central bank losses may attract public attention with suspicions of inefficiency and may lead to scrutiny regarding the measures that caused it. Seigniorage is a form of taxation by a non-elected national authority. Therefore, from a public's perspective, a central bank's profits should be in proportion to the services it provides to the economy and the risks it takes on its balance sheet.

7 This website of the Atlantic Council gives a good overview of QE programmes around the globe: Global QE Tracker - Atlantic Council.

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In exceptional circumstances, the central bank may also choose to support commercial banks by offering them favourable lending conditions. The Eurosystem's targeted longer-term refinancing operations (TLTROs), for instance, provide long-term funding on attractive terms to commercial banks to stimulate bank lending to the real economy. Commercial banks meeting the specific lending thresholds receive a discount on the interest rate that they pay to the Eurosystem.[8]

We conclude that the central bank is a national authority that has features of a commercial bank. Its public role and objective make it comparable to other national authorities, such as supervisory authorities or standard-setting bodies. As in the case of other national authorities, the central bank designs and implements policies and by doing so runs risks associated with ineffective policy implementation. Direct communication to the general public is a way to manage expectations and mitigate reputational risks. Like commercial banks, the central bank also runs significant financial risks, as it implements its policy using its balance sheet. These financial risks are mitigated by sufficient buffers in the form of capital and reserves. Table 1 summarises the main similarities and differences between a central bank and other national authorities on the one hand and commercial banks on the other.

8 Central banks provide liquidity to the banking system but not solvency. Liquidity provision is just an intertemporal transfer to ensure the smooth functioning of the financial system and involvers no taxpayer resources. Solvency transfers do involve public money and are in the domain of politics.

Table 1 The central bank: a national authority with similarities to a commercial bank

	National authority (other than a central bank)	**Central bank**	**Commercial bank**
Role	Public actor	Public actor	Private actor
Objective	Effective and efficient execution of mandate	Independent, effective and efficient execution of mandate (*)	Business continuity and profitability
Tools	■ Policy design ■ Policy implementation	■ Policy design ■ Policy implementation, using its balance sheet vis-à-vis the commercial banks	Balance sheet vis-à-vis the real economy
Risks	Policy risks and reputational risks (**)	■ Policy risks and reputational risks (**) ■ Financial risks excluding liquidity risk, operational risk	Financial risks including liquidity risk, operational risk and reputational risks
Risk mitigation	Communication to public	■ Communication to public ■ Capital and profitability	Capital, profitability and liquidity buffers, transparency vis-à-vis markets

(*) Independence is not a requirement for all national authorities, but it is generally considered a necessary prerequisite for a central bank.

(**) Policy risk is the risk of low effectiveness and efficiency of the national authority.

3 The role of capital for a central bank

In the previous section, we saw that central banks are national authorities with the unique task of designing and implementing monetary policy. In doing so central banks run financial risks. Also, central banks have many similarities to commercial banks, as both rely on adequate capital for loss absorption. This raises the question of the particular role that capital plays for central banks. In this section we review the reasons why a central bank needs capital and a strong balance sheet. We also discuss why adequate capital is less crucial for a central bank than for commercial banks.

3.1 The main arguments in favour of a strong balance sheet

The central bank's balance sheet plays a key role in the implementation of monetary policy. In normal times, the central bank may only be exposed to some credit risk and the market risk of gold and reserves in foreign currencies. In turbulent economic times, financial market participants expect the central bank to step in, defend the currency, support commercial bank funding and take any other necessary measure to restore trust in financial markets. These activities result in financial risks on the central bank's balance sheet that can turn into losses. The central bank should therefore be able to absorb such losses with adequate capital – up to a reasonable level – in a stand-alone capacity for the following two reasons (see, for example, Archer and Moser-Boehm, 2013):

1. **Independence** Adequate capital supports central banks' independence. A key principle in modern central banking is that monetary policy should be conducted independently of politics. A government's interests are diverse and sometimes conflicting. Monetary policy aimed at price stability and financial

stability are deemed too important to be part of trade-offs that concern short-term financial interests of the government. A stand-alone central bank that is independent of the government can fulfil this role in a time consistent manner but needs sufficient resources to do so effectively. Financial independence implies that the central bank generates its own income to pay the necessary costs and holds buffers to be able to absorb the losses it may incur.

2. **Credibility** Adequate capital supports central banks in being credible as a monetary authority. Credibility is essential for a central bank which issues fiat currency as consumers need to trust banknotes. Under normal economic circumstances, monetary policy can be conducted in a straightforward way with the extension of credit to commercial banks, deposit-taking and the use of policy rates as the main parameters. In exceptional economic circumstances, additional measures with more risk may be needed, such as quantitative easing, acting as a lender of last resort to commercial banks or exchange rate interventions. A central bank that is independent of the government needs to be perceived as being able to deploy the necessary strength in these operations.

Together, independence and credibility of the central bank are important preconditions for central bank effectiveness (Blinder, 1998). A country that is committed to an independent central bank can demonstrate that commitment by giving the central bank adequate resources to perform its task independently. The strength of a central bank balance sheet depends on various components such as credit and collateral quality and the amount of gold (as an anchor in

times of stress). In this study we focus on the amount of capital as a key driver of a central bank's financial strength. Capital provides the ultimate loss-absorbing cushion. If the amount of capital is adequate relative to the financial risks on the balance sheet and the latent risks, the balance sheet will be strong.

The central bank's independence has a limited time horizon. On the one hand, it is important that the central bank is shielded from short-term political interference. On the other hand, a central bank – just like any other national authority – is subject to democratic accountability and government control. In the case of central banks, this issue of independence versus government control can be solved by disconnecting the short term from the long term. In the short term, the central bank operates independently of the government to pursue its monetary policy objectives. In the long term, the government controls the central bank's role and functioning by its ability to appoint board members and to propose and implement legal or statutory changes.

Similarly, financial independence of the central bank does not need an infinite horizon. It should, however, be sufficient to bridge the relevant government's policy horizon of, roughly speaking, five to ten years. Beyond that policy horizon the government is in a position to make adjustments it deems necessary. The long-term strategic priorities of the economy and the role of the central bank are defined by the government. Consequently, the capitalisation of the central bank should be such that financial independence is ensured over a medium term of five to ten years.

3.2 Addressing some criticism

A critic can argue that a central bank does not need adequate capital. The critic may cite multiple reasons for that: (a) a central bank can always meet its liabilities by printing money, (b) the government offers (implicit) support to the central bank, and (c) seigniorage acts as a buffer for the central bank. Below we review these arguments.

(a) A central bank can always meet its liabilities by printing money. Although it is true that a central bank technically cannot go bankrupt in its domestic currency, the practice of printing money to cover costs or losses is unsustainable. It will jeopardise public confidence in the central bank and drive up inflation as a result, in an extreme case leading to hyperinflation. A strong balance sheet with adequate capital, on the other hand, supports public confidence as it implies that fiat money as a central bank liability is covered by the central bank's assets. In a way, adequate capital is therefore the successor to the gold standard, ensuring sufficient assets to cover the monetary base.[9] Trust in money is the precondition for the legitimacy of the central bank, which in turn is the foundation for central bank independence, as argued by for instance Braun (2016).

(b) The government offers (implicit) support to the central bank. Some central banks with negative capital seemingly operate without problems. This primarily works, however, because stakeholders such as financial markets and the public

9 The recent developments in some stablecoins shows the importance of backing money by real assets. The crash in TerraUSD, which is backed by an algorithm rather than real assets, triggered a much wider fall in trust in private digital assets. In addition to asset backing, trust in fiat money is also generated by enforcing it as legal tender, ensuring fairness in use and protection of property rights and securing its value from counterfeiting (Vaz and Brown, 2020).

have trust in the government and the strength of the national economy. From a public finance perspective, the central bank's balance sheet can be considered part of the consolidated government's balance sheet. If this consolidated balance sheet is strong, a weak central bank balance sheet may appear to be non-problematic for the role and effectiveness of the central bank. This is because the central bank implicitly relies on the strength of the government. Without the support from the government, stakeholders would perceive a central bank with negative capital as one whose main tool (the balance sheet) is weak and whose liabilities (fiat money) are only partly covered by the central bank's asset values. In a crisis, financial markets will factor in the financial strength of the government, which may be deteriorating at that point as well. In such a situation, there may be limits to what the central bank can achieve on its own in pursuing its objectives. Therefore, a central bank with a negative capital position may not be independent enough and may experience lower credibility.

(c) Seigniorage acts as a buffer for the central bank. Central banks earn income through their conduct of monetary policy because the policy rate for lending is somewhat higher than the policy rate for deposits, generating an interest margin. More importantly, a central bank has a monopoly of the issuance of banknotes, which are liabilities that bear no interest rate. Against these liabilities the central bank invests in assets with positive expected returns. We refer to this collectively as the central bank seigniorage income and this explains why central banks generally make profits.[10] Various efforts have been made to estimate the

10 Seigniorage can be seen as a form of taxation by a non-elected national authority. Whether the central bank's balance sheet should be used as an effective tool to generate public sector income, is a broader question that also relates to optimal taxation policy.

present discounted value of future seigniorage income, assuming it is significant and extends far into the future (see, for example, Buiter, 2008).

However, the amount of seigniorage income is uncertain and depends on the applicable monetary policy in place. In adverse scenarios – and if monetary policy demands it – seigniorage may be low for a long time or even negative for a number of years. Therefore, seigniorage does not help to ensure independence and credibility over the medium term. Even in a normal economic environment seigniorage is notoriously hard to estimate because it requires assumptions about the interest rate margin.[11] It is therefore prudent not to take future seigniorage income into account as a loss-absorbing buffer. This is in line with commercial banks, which likewise do not include their future net income as a buffer. If financial risks were covered by seigniorage only, this would place an additional constraint on monetary policy. The central bank in this case would effectively have to restrict its monetary policy options to those that are profitable over the short to medium term. As a result, such a central bank would have lower credibility as a monetary authority to deploy whatever needs to be done.

3.3 Additional considerations regarding adequate capital

A strong balance sheet with adequate capital is important for an independent and credible central bank, but it is not a sufficient requirement on its own. In order for a central bank to be effective, other conditions need to be fulfilled as well, such as a good central bank law providing a strong legal basis and

11 The introduction of central bank digital currencies may also impact seigniorage in particular if the digital money crowds out banknotes and the central bank remunerates digital money (Kahn, Singh and Alwazir, 2022).

sufficiently high institutional quality of the public sector in a country. A central bank without a proper legal mandate and statutes is less effective. The government's financial position is also relevant. If the government's financial situation has been weak over many years, but the central bank balance sheet remains strong, the central bank may be perceived as less effective by market participants who assess the consolidated public finances. For instance, in emerging market economies, financial conditions may be determined by the government's credit quality and the nation's institutional quality. In such a case, a strong central bank balance sheet is helpful but not sufficient to ensure policy effectiveness. On the other hand, if the deterioration of government finances is temporary and takes only a few years, a well-capitalised central bank may remain effective and bridge this period.

One more perspective in favour of adequate capital comes from the public's perception that the central bank performs banking services for the commercial banks and often manages part of the national reserves in the form of gold and other investments. The public will perceive the central bank as a "bank" that needs to be adequately capitalised. Therefore, from a communication perspective it makes sense to adequately capitalise a central bank, even if the central bank is considered to be a financial subsidiary of the government. As with any other financial subsidiary of a parent company, sufficient capital is needed having regard to the risks that the subsidiary runs. Even if the parent has given the subsidiary an explicit guarantee, supervisory authorities will still require the subsidiary to hold sufficient capital.

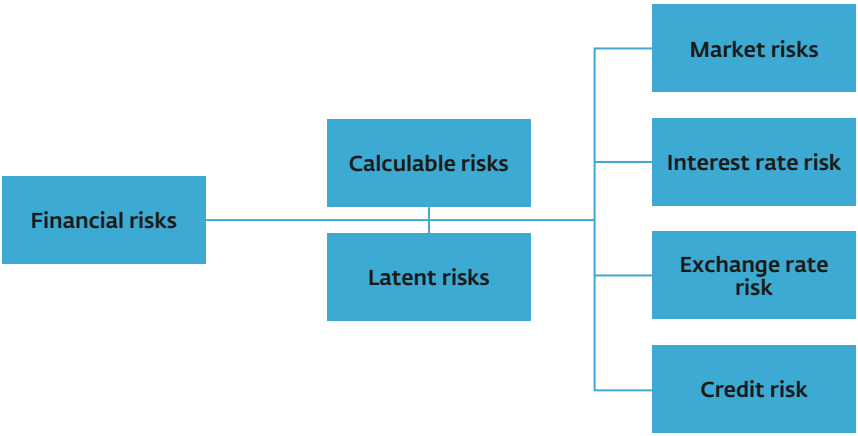
In conclusion of this section, a strong balance sheet gives a central bank sufficient fire power to implement its monetary policy in an effective way. Adequate capital is an important ingredient of a strong central bank balance sheet. It also supports the public's and financial markets' confidence in the independence and credibility of the central bank. With sufficient capital, the central bank can focus on the most appropriate monetary policy without having to consider the strength of its balance sheet or the short-term financial interests of the government. Finally, the public expects adequate capitalisation for a central bank just as for any other bank. This brings us to the next section covering the risks to which a central bank is exposed.

4 The risk exposures of a central bank

In the previous sections we argued that a central bank requires adequate capital to be able to cover the risks of its monetary policy implementation in a stand-alone capacity. In this section we make this more concrete and analyse the risks that a central bank is exposed to and identify the determinants of an adequate level of capitalisation. We start by reviewing the financial risks central banks are exposed to and continue with the relevant risk metrics. We assume that financial risks are *calculable* if they are on the central bank's balance sheet. Next we discuss *latent* risks that come from exposures that are not yet on the central bank's balance sheet but may arise in the future when the central bank takes drastic measures to implement its mandate. At that point latent risks transform into calculable financial risks. Figure 1 presents the risk taxonomy that we use in this paper. We focus on financial risks such as market risk, interest rate risk, exchange rate risk and credit risk.[12] Later on in this section we propose tools to assess the size of latent risks and analyse their drivers.

12 We do not discuss the non-financial risks that are also relevant to a central bank such as operational, reputation, cyber and legal risks.

Figure 1 Financial risk taxonomy for central banks



4.1 Financial risks

Central banks in general hold sizeable amounts of gold and provide credit for commercial banks to execute its monetary policy. A central bank also has a foreign exchange (FX) portfolio for currency intervention purposes and may hold a quantitative easing (QE) portfolio for unconventional monetary policy. Many central banks have an investment portfolio to generate returns, but that is not strictly necessary to implement monetary policy. The liabilities are largely in the hands of the public (banknotes) and commercial banks (deposits). Capital is the shareholder equity on the balance sheet which is available for absorbing losses.

Table 2 Typical items on a central bank's balance sheet and their risks

Assets	Liabilities
Gold (m)	Banknotes in circulation
Credit to commercial banks (c)	Deposits from commercial banks
QE portfolio (c, m)	Capital
FX portfolio (c, m, fx)	
Investment portfolio (c, m, fx)	

(*) credit risk (c), market risk (m), exchange rate risk (fx) and interest rate risk from the asset-liability mismatch (all balance sheet items whose value is sensitive to changes in interest rates)

Table 2 also shows the risks that are embedded in the different asset classes. The gold and FX portfolio usually carry significant market risks but are deemed important for the fulfilment of the central bank's mandate. Central banks are typically averse to accepting credit risk, as large financial risks and losses may have adverse reputational consequences. To reduce credit risks, lending to commercial banks is collateralised and quantitative easing (QE) programmes focus on high-quality paper such as government bonds and investment grade corporate bonds. Also, in their investment portfolios, central banks typically focus on high-quality securities, although equities and high-yield bonds can constitute a part of the portfolio, leading to market risk and credit risk exposures. The FX portfolio and the investment portfolio contain exchange rate risk.

In addition to credit risk, market risk and exchange rate risk, a central bank also faces interest rate risk from the mismatch between assets and liabilities. The values of both assets and liabilities are sensitive to changes in interest rates. This interest rate risk is greater the more the duration of assets deviates from the duration of liabilities. Currently, for many central banks, the duration of assets is longer than that of the liabilities. Such a positive duration gap means that the central bank suffers a loss if interest rates rise. Historically, however, many central banks typically had a negative duration gap, caused by a duration of assets that was lower than the duration of liabilities because the liability side of the balance sheet was dominated by the banknotes in circulation, with a long duration and no coupons.[13]

In recent years, interest rate risk has become a more prominent risk factor for a number of central banks. For these central banks, policy rates have decreased to levels close to or below zero, leading to lower profitability. At the same time, balance sheets have surged due to QE programmes. In such cases, the duration gap has reversed from negative to positive as the long maturities of the QE portfolios exceed the duration of banknotes and deposits on the liability side. For these central banks, years of significant annual losses may occur when the policy interest rates rise quickly and substantially (see, for example, Carpenter, Ihrig, Klee, Quinn and Boote, 2015). The Dutch central bank (DNB) is one of the

13 The most basic interpretation of the duration of banknotes is that it is undefined. Banknotes have no explicit maturity nor coupons. There are, however, other ways to consider the duration of banknotes. First, consumers have the option to exchange banknotes for a deposit at the bank at any given time. This creates a finite duration of banknotes. Second, a country or a central bank has the option to stop circulating banknotes and move to a cashless society. Again this option creates a finite maturity of banknotes. Third, banknotes are regularly taken out of circulation because of damage. Although this creates a finite maturity of a single banknote, it does not change the duration of banknotes as such because the damaged banknote will be replaced by another one.

central banks where interest rate risk constitutes a large part of the risk profile (see DNB, 2015).

4.2 Risk metrics

For commercial banks, several metrics have been developed to measure the level of financial risk. Many of the rules for the minimum capital requirements of commercial banks are derived from such risk metrics. The key examples are Value at Risk (VaR), i.e. the maximum loss on an asset or a portfolio that the bank will not exceed with a certain probability within a given time horizon, and Expected Shortfall (ES), reflecting the average of losses in excess of a given VaR level, again for a certain probability within a given time horizon. Risk managers calculate these metrics using quantitative models or (stress) scenario analysis. VaR and ES are generally accepted metrics used in risk management practice to gauge financial risks.[14]

These metrics are also useful for quantifying the risks embedded in the balance sheet exposures of central banks. A good principle in central bank risk management is to use commercial bank risk management tools unless there is a clear reason why these tools are inappropriate.[15] As the central bank's balance

14 VaR and ES are easy to compute and to interpret. There are, however, also key drawbacks to using these metrics. The major criticism of VaR is that it focuses on risks near the centre of a distribution and ignores tails. Because of that it creates a false sense of control. ES partially overcomes this by incorporating losses in the tail of a loss distribution.

15 In addition to using VaR and ES, taking collateral against credit is also a common risk management practice among central banks. Other practices, such as risk limits and hedges, are less common among central banks. A central bank that sets risk management limits a priori (e.g. vis-à-vis specific banks) severely constrains its policy options and may be forced to drop those limits when a crisis breaks out. In the same vein, hedging interest rate risk with derivatives is undesirable because it would be counter to the monetary policy operation underlying the interest rate risk. In the end, simply absorbing these risks on the balance sheet is often the only option for a central bank.

sheet resembles that of a commercial bank, risks can be quantified by using the measures developed for commercial banks. Indeed, the ECB and the 19 central banks in the Eurosystem, for instance, use such risk metrics in their approach to quantify the financial risks (ECB, 2017).

4.3 Latent risks

In addition to calculable financial risks, a central bank is also exposed to latent risks from exposures that are not yet on its balance sheet. The following two examples explain the concept of these latent risks. First, in its capacity as lender of last resort (LoLR), a central bank may need to provide additional credit to otherwise viable banks that have no other means of borrowing. Once the LoLR credit is provided, it leads to additional exposures and risks on the central bank's balance sheet. Second, QE programmes may be needed to safeguard financial stability by providing ample liquidity to the banking system or to boost inflation by keeping funding costs for governments and corporations low. As a result of purchases of government bonds and investment grade corporate bonds the central bank's balance sheet surges and interest rate and credit risks increase. In such situations, the latent risks transform into calculable financial risks which the central bank accepts under its mandate. In that respect, latent risks are not extraordinary, as they are the same financial risks that we know from normal economic circumstances, except that they originate from exposures which do not yet exist. Central banks' capital can also be used to cover these latent risks. In appendix B we show how latent risks transform into calculable risks.

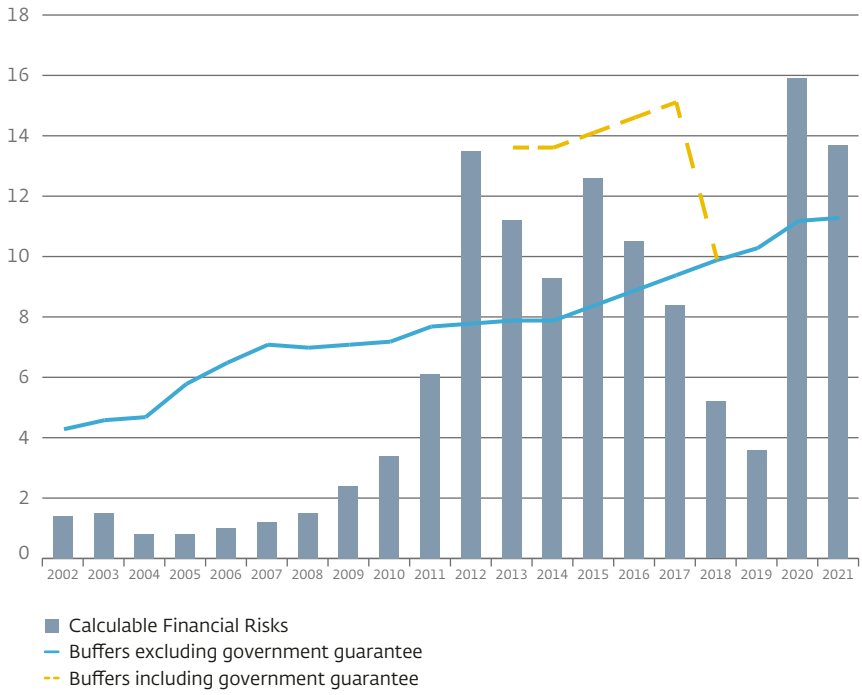
4.4 Assessing latent risks

In the case of latent risks it is unknown a priori where they originate, when they emerge and how large they may be. A central bank acts – within its mandate – to the extent that the economy, inflation, banks or markets need support. The additional financial risks of its policy actions are an accepted consequence and a less prominent consideration in the decision-making. Therefore, quantifying latent risks is harder than for the calculable financial risks that are already on the balance sheet.

One way to gain insight into the latent risks is by analysing the historical evolution of a central bank's balance sheets and risks. As the latent risks emerge during crises and downturns, the comparison between the good and bad economic periods gives an indication of the historical size of latent risks compared to the on-balance sheet risks.

Figure 2 On-balance financial risk profile of the Dutch central bank from 2002 to 2021. .

EUR bn



The figure shows the aggregate level of calculable financial risks; the impact of the latent risks appears in the (sudden) surges in the calculable financial risks when the latent risks transform into additional calculable financial risks as a result of central bank policy actions. Taken and updated from DNB (2018)

As a case study, Figure 2 shows the evolution of the risks and buffers of the Dutch central bank (De Nederlandsche Bank) from 2002 to 2021.[16] The buffers excluding government guarantee consist of capital and a general reserve fund. Clearly visible are the low risks in the period before the Great Financial Crisis of 2008 and the large increase in risks during the European Sovereign Debt Crisis in 2012. Also noticeable are the start and scale-up of the Eurosystem's QE policies in 2015 and the COVID-19 pandemic-related measures in 2020.[17] These external developments were not anticipated upfront and correspond to latent risks transforming into calculable financial risks shown in Figure 1. As a result, DNB's historical risk profile shows an erratic development with rapid rises in calculable risks followed by more gradual declines. This erratic risk behaviour is a key property of a central bank's balance sheet and will continue to occur in the future. Also notice from Figure 2 that the buffers excluding guarantees grow slowly and steadily over time. On average, over this period, DNB has retained 28 percent of its annual net profit to increase equity (DNB, 2022). It is however also clear from the figure that the normal buffers cannot keep pace with an abrupt increase in risks. From 2013 to 2017 DNB had an explicit guarantee from the Dutch government to cover specific risks related to the Euro Sovereign Debt Crisis.

The empirical observation from this case study is that risks for DNB can increase by a factor of three to four in a short period if a crisis erupts. If a sufficiently long historical record of risk measurement is available, this gives a first indication of

16 In addition to capital and a temporary guarantee, the buffers also include a general reserve fund. We will discuss the general reserve fund in Section 6.1.
17 Risks decreased steadily between 2015 and 2020 due to a decreased probability of a sharp interest rate hike.

the size of latent risks. Nevertheless, the origin, nature, size and impact of a new crisis will probably differ from previous crises. Analysing the historical profile of calculable risks can only give a limited view of the size and nature of latent risks.

Another tool to assess the latent risks, therefore, is scenario analysis or stress testing. See, for example, Bakker, van der Hoorn and Zwikker (2011). Scenarios have a forward-looking character and can be developed for current balance sheet exposures or for extreme events leading to additional exposures on the balance sheet. Commercial banks typically focus on the first category, designing stress scenarios with extreme interest rate and credit risk developments. The stress tests of this first category provide a perspective on the financial risks that are similar but complementary to the VaR and ES calculations, as both rely on the exposures that are already on the balance sheet. For central banks, the second category is a more relevant risk management tool because it focuses on the latent risks. While commercial banks typically de-risk during extreme events, central banks are then likely to expand their operations — this implies stress testing needs to take account of additional latent risks. The second-category stress tests provide insight into the sensitivity of the balance sheet size and composition to the extreme policy actions that a central bank may need to deploy every now and then.

Historical experiences provide inspiration for the design of such stress scenarios. Assessments of economic downturns and financial crises over many decades provide a record of sovereign defaults, banking crises and currency depreciations. Analysis of the central bank balance sheet before and after such historic events gives an indication of how much the on-balance sheet risks can increase in

a short period. An alternative, forward-looking method is to start from financial stability reports and design stress scenarios around the vulnerabilities stated in these reports. Financial stability reports are available from the IMF, BIS and, in many cases, a central bank itself. In practice the design of forward-looking scenario analysis is limited by the human imagination and a number of cognitive biases such as the availability heuristic and the confirmation bias. The *availability heuristic* leads the human mind towards risks whose materialisation can be easily imagined. The *confirmation bias* causes people to overlook new risks because we look for information that confirms our existing priors. For instance, the possibility of a disrupting pandemic had been put forward before 2020, but seldom as a prominent risk for the financial sector, whereas today the economic and financial consequences of the COVID-19 pandemic dominate the risk assessments. Therefore, a considerable amount of expert judgment and imagination is needed to design stress scenarios and the policy actions in such a scenario. Ideally people with diverse roles and backgrounds are involved in the expert judgment process to avoid group thinking and obtain dissenting voices (see Broeders, Loman and van Toor, 2019).

The main tools for scenario analysis are stress tests and reverse stress tests. A stress test gives insights into the vulnerabilities to specific scenarios for the risk factors. It is a sensitivity analysis. The results of a stress test are not a prediction with any level of certainty, however. Reverse stress tests help central banks to identify their core vulnerabilities. Reverse stress testing aims to find combinations of risk factors (scenarios) that yield a particular critical loss level. The challenge here is that there are infinitely many combinations of risk factors that yield the critical loss level. Risk managers therefore need to select the most appropriate scenarios and demonstrate the plausibility of those scenarios.

In conclusion of this section, we see that the calculable risks of a central bank can be quite erratic. In a crisis they rise quickly and substantially, only to wane slowly afterwards. Although it is hard to quantify the latent risks that cause this erratic behaviour, we show that they are important to a central bank's risk profile. Any analysis of the central bank risk profile and the corresponding capitalisation should take into account this erratic behaviour through time. In terms of tools, historical analysis of the financial risk profile is useful, but covers only the recent history for most central banks. Forward-looking scenario analyses can provide a complementary view of these latent risks, including the drivers of latent risks, which we cover in the next section.

4.5 The underlying drivers of latent risks

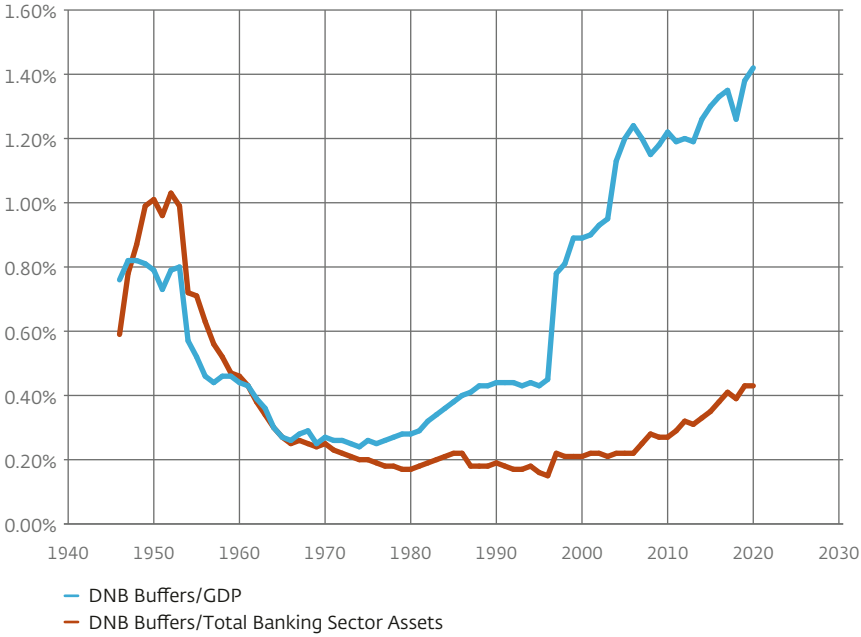
Although the sources of latent risks are by definition unknown, some observations can be made with respect to the mechanisms that are in play. The core indicator is the amount of liquidity a central bank can inject into the financial system, this is loosely related to GDP. First, QE policies use the available instruments in financial markets. A QE government bond programme is therefore limited by the size of the outstanding government paper, which in turn may be related to GDP.[18] Therefore, the latent risks of a QE government bond programme are indirectly proportional to the size of the economy measured by GDP. Second, FX reserves used for interventions grow with the available money supply in order to be effective in a currency crisis. Here too, money supply is connected to the size of the economy. Hence, the latent risks from FX reserves may be implicitly connected to GDP as well. Third, the central bank acts as the

18 In other types of QE programmes, the central bank may also choose to buy other asset classes.

lender of last resort (LoLR) vis-à-vis the banking sector, that can also be related to GDP. Therefore the latent risks related to this role are proportional to the size of the banking sector. More mechanisms can be conceived where the latent risks are connected to fundamental macroeconomic characteristics such as GDP, the size of the financial sector and the money supply.

Figure 3 shows the evolution of DNB's buffers (capital and general risk provisions) relative to the Dutch GDP and relative to the total assets of the Dutch banking sector after World War II. Towards the mid-seventies the ratio of capital to GDP decreased, whilst since then this ratio shows an increasing trend. The ratio of capital to total banking sector assets was fairly stable from the mid-seventies until the start of the Global Financial Crisis in 2008. The upward trend in the two capital ratios is in line with the greater risks that have accrued on DNB's balance sheet. The divergence between the two lines since the early seventies reveals that the banking sector has grown substantially relative to the size of the Dutch economy.

Figure 3 DNB's capital relative to macroeconomic variables



(sources: annual reports DNB and Statistics Netherlands)

Admittedly the connections between capital and macroeconomic variables are indirect and ignore important aspects of the actual underlying risks. For instance, by assuming that the latent risks of LoLR are proportional to the size of the banking sector, we ignore the role of buffers in the banking sector. These buffers have been substantially increased after the Great Financial Crisis and have

therefore significantly reduced the underlying latent risks of a banking liquidity crisis. The same can be argued for other latent risks: debt-to-GDP levels, national balances of payments, equilibrium interest and inflation levels are relevant for the latent risks but are not taken into account in these proportionalities. On the other hand, we do not aim to use these proportionalities for accurate risk modelling. We only aim to establish the drivers of these latent risks. If a country A has a GDP twice the size of an otherwise similar country B, the latent risks of central bank A may also be twice those of central bank B.

An open question is whether central bank interventions change the size of the latent risks. On the one hand, a successful central bank intervention in a crisis may reduce the likelihood of the crisis accelerating. On the other hand, an excessively flexible or lenient policy may lead to moral hazard in the economy, contributing to the emergence of a new crisis. Since there is no clear indication of the correlation between central bank interventions and the size of the latent risks, we will assume for simplicity that the latent risks do not change substantially as a result of policy actions already taken. In conclusion, from these reflections, we infer that the latent risks are connected to fundamental parameters such as GDP, financial sector size and money supply of the country in which the central bank operates. We now turn to the capitalisation of a central bank.

5 The capitalisation of a central bank

In the previous section we saw that a central bank can use its capital to cover both regular calculable risks and latent risks. In this section we consider the target level of capital and the actual capital level versus the target capital. Furthermore, we discuss a central bank's capitalisation from the government's perspective. The two main points are that a central bank's target level of capital can be calibrated with a lower confidence level than that is customary for commercial banks and that it should take into account the latent risks that are proportional to macroeconomic variables such as GDP.

5.1 The target level of capital

So far we have seen that capital acts as a buffer to absorb the financial risks resulting from the central bank's fulfilment of its mandate. That raises the question of how much capital is adequate. There is no consensus within the central bank community on a target level of capital versus the level of financial risks. In their important paper, Archer and Moser-Boehm (2013) give an overview of the diversity of central bank capitalisation practices. Many central banks seem well capitalised, but some operate with negative capital. The capital adequacy standards of commercial banks are not directly applicable to central banks because of the key differences between commercial banks and central banks.

The importance of capital for central banks is indirect and auxiliary. Therefore, it can be argued that central banks can operate with a lower amount of capital than commercial banks. In an extreme scenario of massive financial losses or in the case of a bank run, a commercial bank defaults and discontinues its operations. In the same scenario, a central bank can end up with a negative

capital but in principle continues to operate. In such extreme circumstances, the interests of the government and the central bank are aligned in restoring the economy and the financial sector. A coordinated approach may be required and the goal of central bank independence can be temporarily deprioritised. When the crisis situation is over and financial stability is restored, a realistic roadmap must be presented towards strengthening the central bank balance sheet again. In any case, the impact of such an extreme scenario is less existential for a central bank than for a commercial bank.

A central bank's target level of capital can be calibrated with a confidence level that is lower than that used for commercial banks. Commercial banks are regulated. Using standardised methods from regulation or proprietary models, they are required to maintain a capitalisation that covers the financial risks with the 99.9% confidence level over a one-year horizon (BIS, 2005). In practice, this results in commercial banks holding certain margins in excess of the minimum required capital level. For central banks, there is no regulatory minimum level. And as the relationship of the target level of capital with the objectives of independence and credibility is indirect, a central bank may work with a lower capital target than a commercial bank. This can be translated into the use of a lower confidence level of, for example, 99%. This is the confidence level that the central banks of the Eurosystem use (ECB, 2017).[19]

19 The 99% confidence level proposed here is merely the order of magnitude between the high confidence level applied to commercial banks (99.9% confidence level, on an annual basis) and the next order of magnitude (90%), which seems impractically low. A 90% confidence level corresponds to a policy where the central bank loses all of its capital every 10 years on average. This seems too frequent for a central bank that wants to be perceived by markets and the public as effective on a stand-alone basis. In addition, it could take a long time for the central bank to recover from such a shock using only its own profits.

A central bank's target level of capital should be proportional to (nominal) GDP as a proxy for the latent risks. The target level of capital should grow gradually and steadily over time. As a minimum, the capital target should grow with inflation to maintain its real value. To achieve this, the capital target could be linked to one or more macroeconomic variables. In particular the capital target could be linked to GDP growth. In this way, the capital target will grow steadily in line with the underlying latent risks (which broadly follow GDP) and its growth rate will be within reasonable limits (typically two to five percent per year) even when times are benign or adverse. If over time it is concluded that the latent risks are growing faster than GDP, a recalibration could take place. For instance, this would be justified with a booming financial sector in a country.

Two additional reasons to strive for a gradual and steady growth of the target level of capital are public perception and model risk. First, steady growth of the capital target, when agreed and communicated upfront, creates the perception of being in control of effectively implementing the central bank's mandate. Conversely, large changes in the target level of capital create the perception of reactive, short-term management by the central bank and are potentially detrimental to its effectiveness. Second, financial risk calculations hinge on quantitative analyses, models and parameter estimates. The risk of inaccurate modelling supports an approach that is more prudent with respect to the calculated financial risks and uses a target calibrated against robust parameters with a long-term view. This prudent approach avoids short-term adjustments to the risk calculations and changes in the resulting capital target.

In conclusion, for central banks, the target level of capital can be calibrated at a lower level than for commercial banks, for instance using a 99% confidence level on a one-year horizon. However, unlike the case of commercial banks the capital target should take into account the latent risks. A capital target proportional to GDP or a combination of other macroeconomic parameters is appropriate and practical. The target level of capital should be robust with regard to future developments, i.e. it should continue to be adequate in times of crisis. Ideally the capital target level will be calibrated in such a way that it lies above the calculable risks most of the time. In Table 3 below we summarise the comparison between the target level of capital for central banks and for commercial banks.

5.2 The actual versus the target level of capital

Normally, central banks use their annual profit as the main source of capital growth. Therefore, a central bank should generate sufficient profits from fulfilling its mandate. It may not be easy for a central bank to attract new capital through financial markets or to request the government to transfer extra capital. The latter may be detrimental to a central bank's independence. In line with commercial banks, it seems reasonable for central banks to pay out dividends only when they are not needed for capital growth. However, the government is often the controlling shareholder and should therefore agree to this approach. We will return to this point later.

Over the long term, the annual profits are usually positive and can be influenced by the central bank in order to be sufficient for the purpose of capital growth.[20]

20 For many central banks, the annual profit is an aggregate result of all (monetary policy) operations over the year and not explicitly managed.

Table 3 A comparison between the target level of capital for central banks and for commercial banks

Capital	Central banks	Commercial banks
Necessary	Yes	Yes
Role	Buffer for calculable risks including latent risks	Buffer for calculable risks
Goal	Ensure independence and credibility over the short to medium term	Protection of the bank's depositors and debt investors
Importance to goal	Auxiliary	High
Impact on public trust	Indirect, as trust is inert	Direct, as trust is fragile
Confidence level	No formal requirements; coverage can be e.g. at a 99% confidence level	Formal regulatory requirements based on a 99.9% confidence level
Required size	Capital target related to calculable risks and taking into account latent risks; e.g. proportional to GDP	Directly based on calculable risks
Minimum level	No	Yes, regulatory
Preferred development over time	Target develops gradually; actual capital can be temporarily below target; ad hoc measures not needed	Capital above minimum with a margin; ad hoc measures sometimes needed (e.g. new shares issuance, and recapitalisaton via bail-in)

The profits however also depend on the uncertain returns on the assets that counterbalance monetary liabilities, in particular banknotes.

Steady annual growth of capital cannot be taken for granted. For some central banks, the annual profits can be quite volatile from year to year. Especially central banks with exchange rate objectives and large FX holdings may experience large profits in one year and losses in the next. In these cases, the guidelines in this paper can still be used, but should be applied in a disciplined way. It is important to keep track of the capital target when profits are low or negative. In later years, when profits are higher, the actual capitalisation can grow back to the long-term target. Therefore, it is important that the main shareholder allows full retention of the annual profit, especially in prosperous years. Furthermore, growing back to the target level should be feasible and allowed within a reasonable term, but not beyond the horizon of independence (five to ten years). Obviously, any surplus annual profit that is not needed for capital growth can be paid out to the government in the form of dividend. In the end it is public money that should not accumulate unnecessarily at the central bank. This brings us to the government's perspective.

5.3 Central bank capitalisation from the government perspective

Until now we have discussed capitalisation from a central bank's perspective. The government's perspective, however, is also important. The government finances are directly impacted by the central bank's capitalisation through the dividends that the government receives. In this subsection we assess the capitalisation of the central bank from a government perspective and distinguish various interests of the government. These perspectives played a role in the agreement on DNB's capital policy with the Dutch government in 2019 (DNB, 2018).

First, the government has a key interest in a central bank that is effective in implementing the mandate that it received from the legislator. This requires a central bank's independence from politics and credibility in fulfilling its mandate. Having such a central bank enhances the probability of price stability and financial stability. Any country that has the ambition of long-term economic prosperity ensures that the central bank is given the appropriate legal authority, sufficient resources and qualified staff. Adequate capital to be able to deploy the necessary monetary policy is a crucial part of these requirements.

Second, the government should be cautious not to overcapitalise the central bank. Too much capital in the central bank is inefficient money that cannot be used for the benefit of the general public. Therefore, the capitalisation of the central bank should not be too conservative. This government interest also reinforces the earlier conclusion that a central bank capital policy should not simply be a copy of the commercial bank capital requirements, as that may be too conservative.

Third, the government prefers to receive stable and predictable dividends from the central bank. Government budgeting is a cumbersome process that involves many government departments and political discussions. A lot of effort goes into an efficient and effective allocation of public resources. Big changes lead to renewed discussions and political deal-making. The more ad hoc and frequent these changes are, the higher the likelihood of a suboptimal allocation of public resources. Translating this to the central bank leads to a preference for long-term stable and predictable dividend cash flows.

However, this preference for stable and predictable dividends interferes with the first and second interest of not under- or overcapitalising the central bank. As we have seen, the central bank's annual profits are hard to predict. The development of the balance sheet, the risks and the central bank profits are driven by monetary policy, following the needs of the economy and the financial sector. When priority is given to appropriate capitalisation sourced from the central bank's annual profit, the government receives what is left of the annual profit. With that it has the upside (profits may be large) but also has to accept the downside of dividends that are hard to predict.

In any case, from a government's perspective it is important that the central bank's capital policy is robust. Even when dividends themselves are not predictable and stable, the capital policy should be such that it can accommodate unexpected and extreme situations. A robust policy prevents the unwelcome situation whereby both the central bank and the government have to enter into ad hoc discussions on the adequate capital level, with the possibility of capital injections and attention from the media and politics.

A robust capital policy, which includes the latent risks, provides a backstop to the impact on the government budget in the sense that the dividend payments, though erratic, will not be negative.

6 Types of buffers and the role of accounting methods

We now turn our attention from target capital to available capital and the important role of accounting methods. First, we describe the various types of buffers that can be found on a central bank's balance sheet. Second, we explore the role of accounting in defining buffers.

6.1 Various kinds of capital buffers

So far, we have used the word "capital" as a generic term for describing a central bank's buffer that is available to absorb losses. In practice we observe various kinds of buffers. The key buffers for a central bank are shareholder equity and a general reserve fund. We argue that revaluation reserves for specific assets, a government guarantee and future profits are only effective to a limited extent as a buffer. In this subsection we therefore assess the relevance of these various kinds of buffers.

The ultimate buffer is shareholder equity, i.e. statutory capital plus retained earnings. Shareholder equity provides unlimited loss-absorbing capacity on a stand-alone basis. A general reserve fund (GRF) is also a buffer providing unlimited loss-absorbing capacity. Central banks often have the possibility of accruing such a GRF. It acts in a similar way to capital in that it absorbs financial losses. The main advantage is that additions to and withdrawals from a GRF are under the control of the central bank itself, whereas the distribution of annual profits in the form of dividend is under the control of the shareholder. The central bank board can decide to increase or decrease the GRF before establishing its annual profit. The GRF therefore supports independence from the shareholder, effectively the government. If the GRF covers all the financial risks, we include it in the definition of capital as used in this paper.

Revaluation reserves are asset-specific buffers. Some central banks, such as those in the Eurosystem, have revaluation reserves connected to specific assets on their balance sheet. Revaluation reserves are the result of asymmetric recognition of profits and losses over time. For instance, if an asset generates a marked-to-market profit, this profit is recognised in an asset-specific revaluation reserve. If that asset thereafter generates a loss, that loss is debited from the revaluation reserve and, if this is insufficient, the remainder goes through the profit and loss statement. When the asset is sold or reaches maturity, the revaluation reserve is released and any remaining amount goes through the profit and loss statement. The asymmetric recognition of profits and losses results in significant amounts of buffers on the central bank's balance sheet, especially for exposures with long or infinite maturities such as gold and equities.

Revaluation reserves are not part of capital as described in our paper, however, and are not strictly needed for an effective capital policy. Because revaluation reserves are only available to absorb losses on specific assets, their use as a general buffer is limited. The purpose of revaluation reserves is to prevent capital gains from leaving the balance sheet immediately, in effect helping the central banks to stay away from weak capitalisation, e.g. as a result of the "asymmetric distribution problem" (see the next section). There are pros and cons to using revaluation reserves. Without revaluation reserves any profits are immediately realised and, via the annual profit, end up in the central bank's capital or in the government finances via dividend payments. Revaluation reserves, however, are not controllable, i.e. they follow from accounting rules. The asset needs to mature or to be sold to release the revaluation reserve. As a result, large revaluation accounts may accrue relatively unnoticed by the general

public, reducing their purpose of providing additional comfort on the financial soundness of the central bank.

A government guarantee also has features of a buffer. Guarantees come in many forms, for instance a general first-loss guarantee or a guarantee related to losses on specific assets. DNB had a first-loss guarantee from the Dutch government from 2013 to 2018 covering a number of crisis-related exposures. A government guarantee, however, is not equivalent to capital because it results in dependence on the government. Any significant loss under the guarantee will trigger a process between the central bank and the government to establish the size and timing of the payment. This will have an impact on the government budget and the corresponding media attention and political debate on the decisions of the central bank giving rise to the loss. The central bank may therefore feel restricted when it comes to engaging in necessary policy actions with a financial guarantee from the government. As it is the role of capital to absorb losses on a *stand-alone* basis, a government guarantee is not the most effective instrument. Finally, the central bank is a systemic national authority, which therefore already benefits from an *implicit* guarantee from the government for all of its activities. The question is how much it adds to make this *explicit*.

Future profits or seigniorage do not count as a buffer either. Indeed, seigniorage income may be quite substantial and range far into the future. However, as we have argued already in Section 3, seigniorage income is uncertain and depends on monetary policy. In adverse scenarios – if monetary policy demands it – seigniorage income may be low for a long time or even negative for a number of years.

In conclusion of this subsection, shareholder equity and the GRF act as the only two buffers providing unlimited loss-absorbing capacity on a stand-alone basis. The advantage of a GRF is that it is under the control of the central bank board, supporting the financial independence from the shareholder. However, central banks should be aware of their responsibility and ensure that the use of the GRF is well motivated.

6.2 The role of accounting methods

Buffers and accounting methods are interconnected. Archer and Moser-Boehm (2013) examine the role of accounting methods in analysing central banks' finances. The objective of accounting methods is to present an organisation's financial situation in a transparent and standardised way. Central banks for the most part apply accounting methods used for commercial banks. There are two specific points of attention in the case of central banks. First, whereas commercial banks have numerous shareholders, central banks generally have only one shareholder controlling the dividend policy and capital growth. As we argued in the previous section, the potentially strong influence of the government can be reduced via a GRF that is controlled by the central bank. Second, another challenge is the "asymmetric distribution problem" which occurs when a central bank suffers a large annual loss that may then take years to earn back with small profits.[21]

21 A number of central banks have suffered from this problem. See Archer and Moser-Boehm (2013) for examples.

As a result of their mandates, many central banks have large marked-to-market exposures on their balance sheets, such as FX portfolios and gold. Furthermore, they may be exposed to losses on interest rate risk following a prolonged period of QE, with a commensurately large maturity mismatch on the central bank balance sheet. The annual marked-to-market changes in these assets may occasionally result in a big loss if such a loss is not covered by a revaluation reserve. If such a central bank has a relatively small capital base and low structural profitability, this may result in a long period with a low capitalisation. Archer and Moser-Boehm (2013) devote considerable effort to the asymmetric distribution problem and the way in which accounting methods exacerbate it or can be used to alleviate it.

The asymmetric distribution problem can be reduced with a conservative approach and discipline. First, if the central bank applies conservatism in assessing risks and setting its capital target, annual losses will normally be small in comparison to the amount of capital. Second, if there is nonetheless an annual loss, the central bank and the shareholder should be disciplined in letting the capital grow back to the capital target over time. Such a recovery period may come with increased public attention for the central bank's operations. A clear and transparent capital policy, well explained and applied with a steady hand, will be needed to bridge this period. This brings us to our guidelines for capital adequacy.

7 Guidelines for central banks' capital adequacy

In this section, we translate the key findings from the previous sections into a set of guidelines that can serve as a basis for developing or revising a central bank's capital policy. A key precondition is that the central bank has a clear mandate which it is required to execute independently of the government. How the following guidelines work out in practice depends on the specific situation of a central bank.

Guideline 1

A central bank's capital policy has a target capital level that may correspond to a lower confidence level than the Basel capital requirements for commercial banks.

A central bank cannot default on its own currency. Therefore a central bank's capital is auxiliary in ensuring stand-alone effectiveness, independently of the government. In contrast to the Basel requirements for commercial banks, the central bank's capital target may cover the financial risks with a lower level of confidence, e.g. 99% on a one-year horizon.

Guideline 2

A central bank's capital policy is based on an assessment of financial risks, covering both calculable risks and latent risks.

A central bank needs adequate capital in order to absorb the financial risks in a stand-alone capacity. In doing so, a central bank can use the risk management concepts and risk metrics that are best practice for commercial banks to assess calculable risks. An important difference as compared to commercial banks is that central banks are exposed to latent risks in addition to calculable financial risks. The central bank capital policy should take these latent risks into account.

Historical analyses and scenario analyses can give an indication of the order of magnitude of these latent risks.

Guideline 3

A central bank's capital policy has a target capital level that is stable relative to the key macroeconomic variables and sustainable for a long term.

A central bank's calculable risks can be erratic over time due to the transformation of latent risks into calculable risks. Latent risks are likely to be proportional to macro developments such as GDP and the size of the banking sector. A capital target based on, for example, nominal GDP and calibrated conservatively may cover the calculable risks and latent risks to a large extent.

Guideline 4

A central bank's capital policy focusses on buffers that are directly and unconditionally available to absorb losses.

The loss-absorbing capital should not be subject to any conditions specifying what losses can be absorbed. In addition to shareholder equity, a general reserve fund can be part of capital provided it has a wide-ranging loss-absorbing capacity for a broad range of assets and risk types. Revaluation reserves for specific types of assets and guarantees from the government are not equivalent substitutes for shareholder equity and a general reserve fund.

Guideline 5

A central bank's capital policy relies on the central bank's own profitability for capital growth.

The central bank should use its annual profit as the source of capital growth. If the annual profit is insufficient to achieve the capital target, the central bank should be allowed make this up in later years. Capital which is temporarily below its target level is not problematic as long as recovery is feasible in the medium term (five to ten years). Full retention of annual profit should be undisputed if necessary. Excess profits, when the capital target is reached, should be paid out to the shareholder.

Guideline 6

A central bank's capital policy is robust and objective.

As both annual profits and calculable risks show erratic behaviour, a central bank's capital policy should be robust and be able to accommodate a wide range of states of the economy, from good to bad. Defining a capital target and linking it to GDP creates objectivity. The impact of short-term developments such as losses or sharp increases in calculable risks to capital should be clear and undisputed, preferably based on pre-defined, objective criteria, with limited discretion.

Guideline 7

A central bank's capital policy is simple and transparent.

The capital policy should be made public in a way that can be easily understood by stakeholders and the public. Every year the central bank should explain how capital is growing in relation to the target and the calculable risks.

The effectiveness of the capital policy could be evaluated and published on a regular basis, for instance every five years.

Table 4 Guidelines for central bank capital policy

Guideline	A central bank's capital policy...
1	has a target capital level that may correspond to a lower confidence level than the Basel capital requirements for commercial banks
2	is based on an assessment of financial risks, covering both calculable risks and latent risks
3	has a target capital level that is stable relative to the key macroeconomic variables and sustainable for a long term
4	focusses on buffers that are directly and unconditionally available to absorb losses
5	relies on the central bank's own profitability for capital growth
6	is robust and objective
7	is simple and transparent

8 Central banks in a monetary union and further discussion

The guidelines in the previous section are generic. So far we have assumed that the central bank is the sole monetary authority in its jurisdiction and has full control over the national currency. This is not the case, however, for national central banks that are part of a monetary union such as the Eurosystem. Below we first elaborate on the implications of capital adequacy of national central banks in the Eurosystem. In the second subsection we discuss central bank risk management.

8.1 A national central bank in the Eurosystem

The main messages of our paper also hold for a national central bank (NCB) in the Eurosystem. The objective of the Eurosystem is to achieve price stability. The role of an NCB is still the same as a central bank outside a currency union: they are the national monetary authorities, they have similarities to commercial banks, but they cannot default as long as the euro is accepted as legal tender. Also, they run financial risks and rely on their credibility and independence from the governments in fulfilling their mandates. Hence, NCBs in the Eurosystem also require adequate capital to be effective. It is also clear that the Treaty mandates the Eurosystem to implement monetary policy measures to achieve price stability, even if it results in losses for the Eurosystem or individual NCBs (Donnely et al., 2017).

There are also differences compared to central banks in a single currency-country setting. The individual NCBs of the Eurosystem are not in control of monetary policy. They execute the decisions of the ECB Governing Council, in which each governor of an NCB has a vote. The resulting common monetary

policy operations do not leave much freedom for individual choices at the NCB level. Generally, the financial risks of the monetary policy operations are shared between the NCBs in the Eurosystem.[22] But there are non-monetary activities that NCBs can pursue with some freedom at their own risk. These range from providing investment services to selected clients such as central banks outside the Eurosystem to managing own investments, gold reserves and FX holdings. These non-monetary parts of the NCB balance sheets are nonetheless subject to rules and bandwidths in order for the Eurosystem Governing Council to maintain control of the overall monetary stance.

Buiter (2015) argues that being part of the Eurosystem means that the NCBs are less like normal central banks and more like currency boards.[23] This in fact increases the need for NCBs to be adequately capitalised. The author argues that capital adequacy matters for individual central bank because in absence of unlimited loss-sharing they could become insolvent even if the Eurosystem as a whole remains solvent. As in the case of a single currency-country central bank, a Eurosystem NCB needs capital for the purpose of independence, covering the risks that result from monetary policy implementation.

From a consolidated perspective, the capitalisations of the individual NCBs in the Eurosystem are less relevant, as long as the financial strength is sufficient on the aggregate Eurosystem level. Indeed, we saw in the Euro Sovereign Debt

22 The Governing Council may decide to deviate from this principle as it did, for instance, for the Public Sector Purchase Programme (PSPP).
23 A currency board is a monetary arrangement whereby a fixed exchange rate is maintained with another currency and all monetary liabilities are backed by reserves in that currency.

crisis in 2012 and 2015 that an NCB can be close to "failure", with a sovereign that is effectively in default. The Bank of Greece nevertheless continued to function with the support of the Eurosystem. The risk-sharing in the Eurosystem provides an additional benefit to NCBs, alongside central bank capital. Nevertheless, on an aggregate level the capitalisation of the Eurosystem should still be adequate, and each NCB should contribute its part.

In conclusion, being part of a currency union such as the Eurosystem may not fundamentally change the need and requirements of a capital policy for a central bank. All individual central banks in the Eurosystem in general still require adequate capitalisation in order to be effective individually and collectively, independently of the governments.

8.2 Central bank risk management and capital policy

Central bank risk management is a rather young discipline.[24] Central banks are institutions created to absorb risks when they emerge. Put differently, they accept risks when other market participants no longer do so, by acting as a lender of last resort and by taking liquidity measures to address market malfunctioning. Central banks' prime task is to safeguard price and financial stability and this may entail accepting risks that private institutions do not accept. While making a profit and mitigating risks are not prime objectives, central banks need nonetheless risk management to remain adequately capitalized to be credible and independent.

24 See ECB (2004) for an early book on the topic. An overview of the financial risk management in the Eurosystem is presented in ECB (2015).

As central bank risk management is still in a developing phase, financial risk calculations typically do not go back more than 20 years. It would be interesting to apply proxy risk calculations to the historical balance sheets of a large number of central banks over a longer period of time (say: 50 years). Such an analysis gives more insight into the diversity and variability of the calculable risks and hence the transformation of latent risks into calculable risks over time. This could give further insight into the connection of the latent risks with macroeconomic variables such as GDP and the size of the financial sector.

Some central banks already use a policy where capital is calibrated vis-à-vis GDP. The Dutch central bank (DNB) has had a capital policy since 2019 (DNB 2018, DNB, 2019) which is based on risk calculations including calculable and latent risks and featuring a capital target whose growth is linked to the growth of GDP (see also Box 1). This policy has been developed in cooperation with the Dutch Ministry of Finance (DNB, 2018). The Treasury's budgetary interests have been explicitly taken into account and the general reserve fund is built up specifically for latent risks transforming into calculable risks such as from QE. The Swiss National Bank (SNB, 2021) has already had a capital growth target linked to GDP for a long time. In 2009, it was amended to accommodate the SNB's increased risk profile. Since then, the capital growth target has been twice the average GDP growth over the last five years. The Danish central bank also aims for capital to grow in line with GDP over the years (DN, 2018). The target capital of Sveriges Riksbank growths with inflation. Interestingly a new act in Sweden will set rules for dividends and equity based on this target level for equity (Kjellberg and Åhl, 2022). If the Riksbank makes a profit that results in equity

exceeding the target capital, the profit surplus is paid out as dividend. If, on the other hand, the Riksbank's equity falls below 1/3 of the target level, the Riksbank shall automatically asks for a recapitalisation. The amount requested shall bring capital back to 2/3 of the target level.

A recent development in central bank risk management is the acknowledgement of climate change related risks as a source of financial risk. Central banks are exposed to climate change through their asset purchase programmes and credit operations. Risk management in this case is challenging because climate change is surrounded by fundamental uncertainty (Broeders and Schlooz, 2021). The Eurosystem is moving ahead ambitiously on this front with its climate action plan.

9 Conclusion

Central banks are a diverse community. One could argue that the framework we present in this paper does not work for all central banks. There are central banks with large balance sheets and high risk exposures, and there are central banks with lower risks. Some central banks have only a few types of exposures with only some credit risk, while others are exposed to almost all risk types. Our guidelines can be tailored specifically to each central bank. The starting point is a solid assessment of calculable risks, according to market practice, that differentiates between the asset types and risk types. Furthermore, some effort must be put into assessing the latent risks and calibrating the target capital level, e.g. vis-à-vis GDP.

In this study, we argue that central banks need adequate capital in order to be effective as a monetary authority, independently of their governments. In this way, central banks differ from commercial banks. For the latter, adequate capital is essential to protect depositors and bondholders and maintain public trust. Commercial banks can default. For central banks, capital plays a more indirect, auxiliary role, in that it helps to maintain confidence that the central bank is pursuing an appropriate monetary policy and is able to absorb the corresponding financial risks on a stand-alone basis, independently of the government.

We present guidelines to determine an adequate level of capitalisation for a central bank. Central banks should calibrate a target level of capitalisation based on the financial risks, including the latent risks from possible future policy operations. The target level of capitalisation can correspond to a lower financial risk confidence level (e.g. 99%) than the 99.9% confidence level of commercial

banks reflecting the auxiliary role and the fact that central banks cannot default. The chosen target level can be proportional to a macroeconomic parameter, such as GDP, as a proxy for latent risks, ensuring a steady development over time. The actual level of capital grows from the central bank's own profits and may undershoot the target level in certain years. This is not problematic as long as the return to the target over a medium-term horizon (five to ten years) is realistic. In addition, sudden increases in the calculated financial risks (i.e. latent risks transforming into calculated risks) are not problematic as long as this situation is expected to be temporary. Capital adequacy will get significant attention over the next years as many central banks have to draw on their buffers following rising interest rates in line with high inflation. Because many central banks accrued large monetary portfolios with (government) bonds they are exposed to increasing interest rates. Our study offers some guidance here.

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Appendix A: Definitions

Buffers – all on-balance and off-balance sheet items with the capacity to absorb losses, i.e. capital, revaluation reserves and guarantees

Calculable financial risks – all financial risks based on the current balance sheet exposures that can be estimated with market practice risk models. Calculable financial risks do not include latent risks.

Capital – shareholder equity on the balance sheet available for absorbing losses, typically statutory capital, plus retained earnings, plus other provisions or reserves with broad loss-absorbing capacity (such as the general reserve fund). Revaluation reserves and guarantees are not included.

Capital policy – the policy that governs the target level of capital vs the actual level of capital, including the retention and pay-out of annual profit.

Central bank independence – precondition for central bank effectiveness over the short to medium term (up to five to ten years). Independence from the government includes legal independence, personal independence and financial independence. Sufficient capital ensures financial independence.

Fiat money – A currency or medium of exchange without intrinsic value. A central bank maintains its value, or parties engaging in exchange agree on its value.

Financial risks – market risks, credit risks, exchange rate risks and interest rate risks, both calculable as well as latent risks. This also includes liquidity risks, although these are usually not relevant for central banks.

General reserve fund – equity item recognised for general losses in the future, not yet incurred or identified at present. In this paper, we consider the general reserve fund part of capital. The general reserve fund at a central bank differs from the more common accounting provisions at regular institutions, such as commercial banks, which are recognised for incurred losses or costs.

Guarantee – agreement with third party to cover losses. In the case of a central bank the third party is typically the government.

Latent risks – all financial risks based on future exposures that the central bank accepts under its mandate. Latent risks are by definition non-calculable but can transform into calculable risks, e.g. when policy measures such as QE and LOLR are deployed.

Leverage ratio – the ratio of total assets to available capital.

Non-financial risks – operational risks, reputation risks, cyber risks and legal risks, both calculable and non-calculable. These are not considered further in this paper because they are (or are expected to be) small compared to financial risks for a central bank.

Revaluation reserve – equity item on the balance sheet that is only available to absorb specific losses, usually connected to specific instruments or asset types (such as gold).

Seigniorage – the present value of future annual profits of the central bank up to the medium term (up to five to ten years). This value may be large, but can also be small in an adverse scenario. Note that this is a broader definition than the difference between the face value of banknotes and their production costs, which is often used elsewhere.

Target capital level – the amount of capital that the capital policy specifies as desirable in relation to the financial risks, including the latent risks.

Appendix B: Latent risks transforming into calculable risks

In this appendix we present an example of balance sheet risk calculations, and estimate the size of latent risks as a result of additional policy actions. We start by assuming a balance sheet without taking the latent exposures into account and determine the size of the calculable risks embedded in the balance sheet relative to the available capital. Thereafter we expand the example by incorporating latent risks. We will see that the latent risks involve a volume effect whereby the size of specific balance sheet items increases depending on the type of policy action.

We start by assuming that a central bank has a stylised balance sheet as shown in Table A.1. The assets consist of credit operations with banks (C), a QE programme with bonds in the local currency (B), an intervention portfolio with bonds in foreign currency for intervention purposes (F) and gold (G). The loans to banks in the credit operations are collateralised. For ease of exposition we assume that the credit risk on all bonds is negligibly small and that the currency risk is unhedged. On the liability side we find banknotes (N) and deposits from commercial banks (D). We assess all balance sheet items in economic terms, implying that the available capital (E) is the residual of all other balance sheet items, i.e.,

$$E=G+C+B+F-(N+D).$$

Table A.1 Stylised central bank balance sheet

Assets		**Liabilities**	
Gold	G	Banknotes in circulation	N
Credit to commercial banks	C	Deposits from commercial banks	D
QE portfolio	B	Capital	E
FX portfolio	F		
Total assets	A	Total liabilities	L

The first step is to assess whether the available equity is sufficient to absorb calculable risks. We assume that the central bank is exposed to $j=4$ sources of risk: credit risk, interest rate risk, currency risk and gold price risk. For simplicity we assume that only the assets are affected by these risk factors.[25] We furthermore assume that credit risk, currency risk and gold price risk (represented by a loss y_j in euros) can be captured as an extreme, instantaneous shock (represented by a factor ε_j in percentage points) on the value of the balance sheet items above. These shocks can be calibrated on historical data on a specific confidence level α, for example 99 percent on a one-year horizon. For credit risk the size of the shock depends on the credit risk of the counterparties and that of the posted collateral. For the sake of simplicity we assume that the net economic exposure can be captured by a single risk factor. For interest rate

25 Interest rate risk relates to the sensitivity of the entire balance sheet to interest rates due to the asset and liability duration mismatch. For simplicity we assume that gold, the FX portfolio, banknotes in circulation and the deposits from commercial banks are not sensitive to changes in interest rates – an assumption that is easy to change.

risk the impact of the interest rate shock Δi depends on the duration D_B of the bond portfolio. Finally we assume that all n risk factors are uncorrelated, which implies that the central bank has diversification benefits. Under this assumption total calculable financial risks Y is given by

$$Y = \sqrt{\sum_{j=1}^{4} y_j^2}\,.$$

Where y_j is the calculable financial risk for risk source j (*for j=1,..,4*) that can be calculated in the following ways

Credit risk: $y_C = \varepsilon_C C$
Currency risk: $y_{FX} = \varepsilon_{FX} F$
Gold price risk: $y_G = \varepsilon_G G$
Interest rate risk: $y_R = -\Delta i\, D_B B$

We can now apply some arbitrary numbers to get the current balance sheet as presented in Table A.2. The initial central bank's leverage ratio is (260/30=) 8.7.

Table A.2 Current economic central bank balance sheet

Assets		**Liabilities**	
Gold	30	Banknotes in circulation	50
Credit to commercial banks	30	Deposits from commercial banks	180
QE portfolio (duration 7 years)	150	Capital	30
FX portfolio (short duration)	50		
Total assets	260	Total liabilities	260

Next we assess the size of the calculable financial risks. We assume a negative shock in the credit risk factor of ε_C=-0.167 (or -16.7%). If we multiply this by the economic exposure of C=30, we get a calculable risk of -5 for credit risk. The shock in the exchange rate risk factor is ε_{FX}=-0.200 and for gold price risk it is ε_G=-0.167. The shock in the interest rate risk factor is an increase in interest rates of 100 basis points (or Δi=0.01). This creates a loss on the QE portfolio with a duration of seven years of -10.5. Note that these are fictional numbers just to illustrate how the method works.

Table A.3 Calculation of financial risks on current economic balance sheet

Risk source	Shock risk factor	Economic exposure	Calculable risk
Credit risk	-16.7%	30	-5
Exchange rate risk	-20%	50	-10
Gold price risk	-16.7%	30	-5
Interest rate risk	+0.01	-7*150	-10.5
Total risks			16.1

Using the aggregation formula shows that the total calculable financial risk amounts to 16.1. This means that in an extreme scenario the central bank loses 16.1 on its available capital. Since the available capital is 30, the central bank can absorb these calculable risks. After that the central bank can restore its capital by retaining future profits.

The second step is to quantify latent risks. We assume that these latent risks lead to a volume effect on the central bank's balance sheet. However, we assume that the latent risks do not change the size of the risk factors (ε_j). We assess three examples of latent risks: a surge in the liquidity provision to the commercial banking sector, a significant expansion of the QE programme to steer inflation and a sharp increase in FX purchases to steer exchange rates.

Scenario 1: A surge in the liquidity provision to the commercial banking sector. In an economic downturn the central bank may be called upon to provide extra liquidity to the banking sector in its capacity as lender of last resort. We assume that credit to commercial banks expands rapidly and increases by a factor of five. The additional credit to commercial banks appears on the asset side of the central bank's balance sheet. The central bank funds this additional credit by simultaneously increasing the commercial banks' deposits on the liability side of its balance sheet. This process creates money and is referred to as mutual debt acceptance. We can now perform a new risk analysis, which is similar to the base case. Table A.4 shows the risk calculation in scenario 1 (changes compared to the base case are highlighted in bold). The total risks, including this latent risk, now amount to 29.3, an increase of 13.2 on top of the 16.1. Total risks are still marginally smaller than available capital.

Table A.4 Calculation of financial risks after a sharp increase in liquidity provision to the commercial banking sector

Risk source	Shock risk factor	Economic exposure	Calculable risk
Credit risk	-16.7%	**30*5=150**	**-25**
Exchange rate risk	-20%	50	-10
Gold price risk	-16.7%	30	-5
Interest rate risk	+0.01	-7*150	-10.5
Total risks			**29.3**

Scenario 2: Significant expansion of the QE programme to steer inflation. In order to steer inflation the central bank may decide to expand its QE programme in the future. To assess the latent risks we assume that the QE portfolio doubles in size through purchases of government bonds from commercial banks. The central bank again funds this expansion by simultaneously increasing the deposits from commercial banks on the liability side of its balance sheet. Table A.5 shows the risk calculation in scenario 2. The total risk amounts to 24.3, up 8.2 from 16.1 in the base scenario due to the transformation of latent risks into calculable risks.

Table A.5 Calculation of financial risks after a significant expansion of the QE programme

Risk source	Shock risk factor	Economic exposure	Calculable risk
Credit risk	-16.7%	30	-5
Exchange rate risk	-20%	50	-10
Gold price risk	-16.7%	30	-5
Interest rate risk	+0.01	**-7*2*150**	**-21**
Total risks			**24.3**

Scenario 3: A sharp increase in FX purchases to steer exchange rates. In order to influence the exchange rate the central bank may decide in the future to buy additional bonds in foreign currency. We assume that in an extreme scenario the central bank triples its FX portfolio. Table A.6 shows the risk calculation in

scenario 3. The total risks amount to 32.5, up 16.4 from the original 16.1 due to the transformation of latent risks into calculable risks. For the sake of simplicity, we assume that the central bank is successful in keeping exchange rates constant, so the FX portfolio does not change in value.

Table A.6 Calculation of financial risks after a sharp increase in FX purchases

Risk source	Shock risk factor	Economic exposure	Calculable risk
Credit risk	-16.7%	30	-5
Exchange rate risk	-20%	**3*50=150**	**-30**
Gold price risk	-16.7%	30	-5
Interest rate risk	+0.01	-7*150	-10.5
Total risks			**32.5**

We can see that the central bank has sufficient available capital to absorb the transformation of latent risks into calculable risks in scenario 1 or 2. However, the latent risks in the third scenario would increase the central bank's risks in excess of available capital. Nevertheless, this does not imply that the central bank needs to start increasing its capital or discontinue its intervention. We argue that a central bank's capital should cover a wide range of scenarios where latent risks transform into calculable risks, but not all. Over time capital should growth in line with macroeconomic variables to be balanced relative to the size of the economy.

82 The main challenge of the analysis in this appendix is how to calibrate the volume effects for the latent risks *a priori*. The shocks in the risk factors are to some extent straightforward because they can be calibrated using a long series of historical data on the risk factor, and may not change directly in a scenario where latent risks transform into calculable risks. For the volume effects this is harder as these are the direct consequence of the extent of the policy action.

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