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Economic Synopsis
On the solvency and credibility of a central bank

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Abstract
This synopsis discusses the financial boundaries of central banks' actions. Under extreme conditions, a weak financial situation could interfere with monetary policy objectives, but the literature suggests that the likelihood of such an event occurring in an advanced economy is very low. Currently high balance sheet exposures leave central banks vulnerable to income losses, but this does not need to affect monetary policy credibility. This discussion is at the core of monetary and fiscal policies interactions. Understanding these mechanisms is important to ensure that episodes of policy insolvency remain only in the realm of a theoretical possibility. (JEL: E52, E58, E63, H63)

Keywords: Central bank balance sheet, monetary-fiscal interactions, central bank independence, monetary policy credibility.

"As recent events should have taught us, historically abnormal events do occur in financial markets, and understanding in advance how they can arise and how to avert or mitigate them is worthwhile."
Del Negro and Sims (2015)

1. Introduction

Can a central bank go bankrupt? For a central bank whose liabilities are denominated in nominal terms and in the domestic currency the simple answer is no. Any central bank in these circumstances can simply issue additional

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currency to cover its nominal financial obligations.[1] This answer may erroneously lead to the conclusion that central banks are not confronted with financial restrictions in the pursuit of their activities. This is certainly not the case. This synopsis discusses precisely the financial boundary of central banks' actions and the conditions under which a central bank may become unable to fulfil its mandate due to a lack of financial resources, i.e. it becomes 'policy insolvent'.

A central bank may be policy insolvent if it departs from its objectives to satisfy its financial obligations, e.g. by allowing inflation to increase above its target. In extreme cases, this may result in a loss of confidence in the currency, leading to hyperinflation and strong depreciation. There are several historical examples of such episodes, in European countries in the 1920s (e.g. Germany) or Latin American countries more recently (e.g. Argentina and Brazil in the 1980s or Venezuela since 2015).[2] The literature has related these episodes with unsound interactions between monetary and fiscal policies.[3]

While there is no evidence that such a chain of events may occur in the near future in any advanced economy, the issue regained relevance in the past decade, as central banks' balance sheets increased significantly in size and risk exposure. Figure 1 presents the evolution of central banks' total assets in the four major advanced economies and figure 2 a decomposition of the balance sheet in the cases of the Eurosystem and the Federal Reserve. Until the global financial crisis in 2008, central banks' balance sheets were relatively small and the asset side mainly comprised collateralised short-term credit operations with financial institutions (in the case of the Eurosystem) and US Treasury bills and bonds mostly with short duration (in the case of the Federal Reserve). Since then, balance sheets increased significantly and their composition tilted towards longer-term operations, leaving central banks more exposed to interest rate risk and sovereign credit risk. On the liability side, before the financial crisis operations were mainly financed through currency. Since 2008, interest-bearing reserves played an increasing role and currently represent a substantially higher portion of central banks' liabilities.

As it will probably take some time before central banks' balance sheets return to the pre-2008 configuration, this evolution has raised concerns over central banks' profitability in the coming years, namely in the event of higher policy rates. Can the materialisation of these risks lead to policy insolvency? Can the potential impact of monetary policy measures on a central bank's net income influence its decisions? It

1. The answer would be different for a central bank with real liabilities (e.g. indexed to inflation or denominated in a foreign currency). In such cases, formal insolvency is possible. Throughout the analysis we will focus on the more interesting case of central banks that mainly issue nominal liabilities denominated in the domestic currency, where 'formal insolvency' is not an issue, but 'policy insolvency' could still occur.

2. See Quinn and Roberds (2016) for an earlier example of a reserve currency (the Dutch florin in the 18th century) that lost its status in the aftermath of accommodative policies that resulted in substantial financial losses for the central bank.

3. See Kehoe and Nicolini (2021) for a thorough discussion of monetary and fiscal policy interactions in Latin America since 1960 and its implications for inflation and economic well-being.

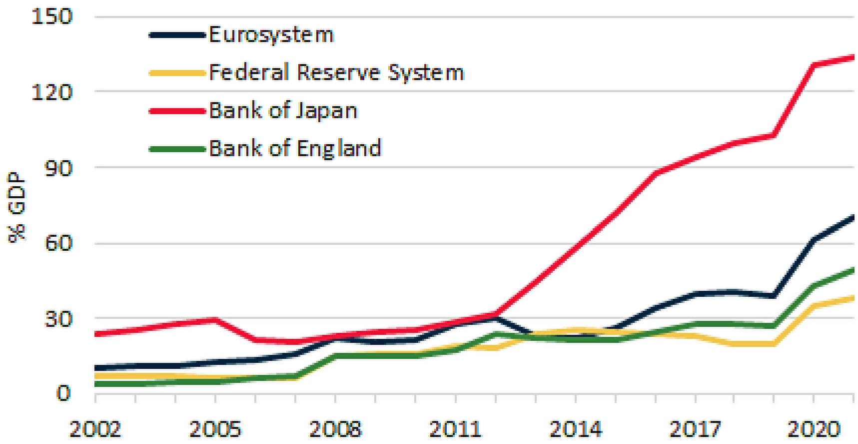
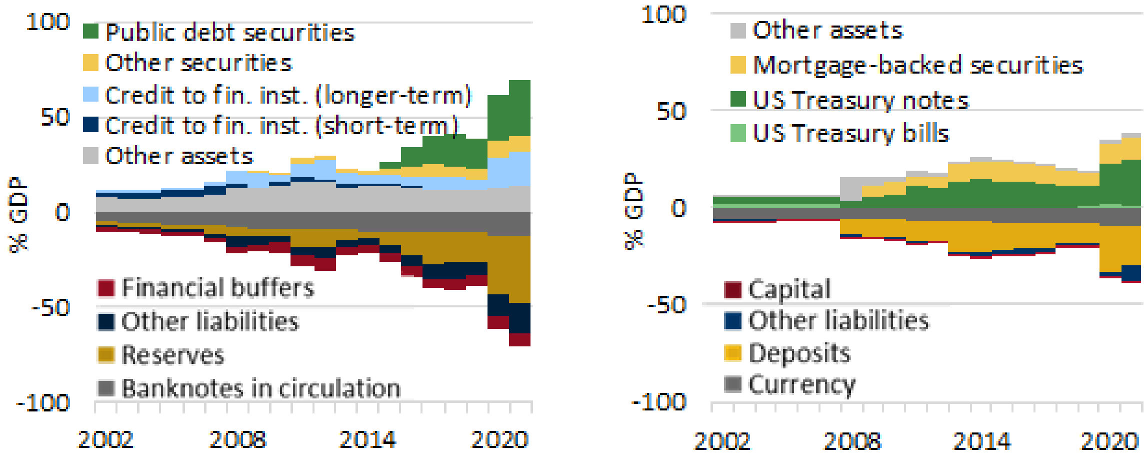


FIGURE 1: Central banks' total assets in selected advanced economies

Notes: Positions at the end of each calendar year. | Latest observations: 2021.
Sources: European Central Bank, Federal Reserve System, Bank of Japan and Bank of England.



(A) Eurosystem (B) Federal Reserve System

FIGURE 2: Composition of the balance sheet in the Eurosystem and the Federal Reserve System

Notes: Credit to financial institutions (longer-term) includes all operations with maturity greater than or equal to three months. | Latest observations: 2021.
Sources: European Central Bank and Federal Reserve System.

should not. Hence, understanding the conditions that could lead to policy insolvency is crucial to ensure the credibility of monetary policy.

We start by discussing how the literature has dissected the fundamental interactions of monetary and fiscal policies. In section 2, the two necessary conditions to ensure that monetary policy can sustain a price stability objective are clearly identified: (i) fiscal policy needs to guarantee public debt sustainability for any given level of prices ('monetary dominance'); (ii) the fiscal authority ensures the recapitalisation of the central bank in case of need ('fiscal support').

When the second condition is not met, the central bank needs to satisfy an autonomous budget constraint that can serve as a reference for the definition of the central bank's solvency. This is discussed in section 3 for the case of a single central bank and a single fiscal authority, where we lay out some general principles suggested by the literature. The consensus is that the likelihood of central bank insolvency is negligible when the central bank's assets are mainly short-term, carrying little interest rate or credit risk, and interest-bearing reserves are inexistent or residual. Things could change when a large amount of interest-bearing reserves is issued to finance a large set of assets with a substantially different risk-return profile. In any case, the available estimates suggest that this likelihood is very small.

In a monetary union, the issue poses additional challenges, given the complex web of interactions between national central banks (NCB) and national fiscal authorities. This is discussed in section 4. While the credibility of the single monetary policy still hinges on a similar solvency constraint at the aggregate level, understanding how national level concerns may or may not spill over to the aggregate level is important. Section 5 briefly discusses proposed alternative mechanisms to support the financial strength of a central bank in case of absence of an explicit 'fiscal support' and explores in some detail the institutional arrangements observed in major advanced economies. In the case of the Eurosystem this is mainly achieved by increasing capital or financial provisions.[4]

Section 6 provides some concluding remarks. The likelihood of central bank insolvency in an advanced economy is very small from an intertemporal perspective. However, any eventual pressure to maintain positive dividends could raise doubts on whether monetary policy decisions would be guided by concerns over the central bank's financial situation. The conduct of monetary policy ought to be guided by the central bank's mandate. Hence, the institutional framework should continue enforcing mechanisms to ensure the central bank's independence.

2. Fundamental interactions between monetary and fiscal policies

The literature has long understood that monetary and fiscal policies interact in several dimensions. In a seminal contribution, Sargent and Wallace (1981) show how this relationship is inextricably linked by the consolidated budget constraint of the public sector (i.e. including the central bank and the rest of the government). In their setting, if the fiscal authority significantly increases the budget deficit and public debt without any intention to offset that by raising taxes or reducing spending in the future ('dominant fiscal policy'), then the monetary authority has no option but to raise seignorage revenues (and inflation) if it cares about the solvency of the public sector. This result suggests the need for fiscal policy to ensure the sustainability of public debt for any given price level in order for monetary policy to be able to fulfil a price stability

4. The ECB's risk management principles (European Central Bank 2015) stress the importance of using the risk capacity of the Eurosystem in the most efficient way (i.e. aiming to achieve the policy objectives with the lowest possible risk) and explicitly acknowledge that "the ECB and the NCBs need to have enough net equity – in case of losses – in order to minimise reliance on capital injections".

objective. Henceforth we will denote this condition by 'monetary dominance' (or 'no fiscal dominance'), following the terminology used by Sargent and Wallace (1981).[5]

To understand this, consider the following simplified version of the flow budget constraint of the public sector:

$$B_{t-1} + M_{t-1} \leq \frac{1}{1+i_t} B_t + M_t + P_t \tau_t \tag{1}$$

where B_t are one-period government bonds held by the private sector outstanding at the end of period t, issued at discount with a nominal risk-free interest rate i_t, M_t is currency in circulation at the end of period t, P_t is the price level in period t and τ_t is the real primary surplus of the government in period t.

Following Benigno and Nisticò (2020), we define the flow of real seignorage revenues as $s_t = \frac{i_t}{1+i_t} \frac{M_t}{P_t}$, which represents the interest saved by issuing money balances that carry no nominal cost. Then, the flow budget constraint can be rewritten as:

$$B_{t-1} + M_{t-1} \leq \frac{1}{1+i_t} (B_t + M_t) + P_t \tau_t + P_t s_t \tag{1a}$$

The interpretation is simple: in every period, the public sector must finance its liabilities with the issuance of new liabilities or the resources obtained either from primary surpluses or from seignorage revenues.

Iterating forward and assuming a condition that prevents the public sector from sustaining an ever increasing value of liabilities (likewise a Ponzi scheme),[6] we can obtain the following intertemporal budget constraint for the consolidated public sector:

$$\frac{B_{t-1} + M_{t-1}}{P_t} \leq E_t \left[\sum_{T=t}^{\infty} v_{t,T} (\tau_T + s_T) \right] \tag{2}$$

where $E_t[.]$ represents an expectation based on the set of information available at the end of period t and $v_{t,T}$ is the real stochastic discount factor between periods t and T. In a setting with risk-free nominal assets, the real stochastic discount factor can be given by $v_{t,t} = 1$ and $v_{t,T} = \prod_{j=t+1}^{T} [\frac{1+\pi_j}{1+i_{j-1}}]$, for $T \geq t+1$, where π_t is price inflation between periods $t-1$ and t.[7] Under rational expectations, agents are assumed to know the model and policy rules that govern these stochastic variables, so the expectation in the right-hand side of condition (2) would be consistent with fundamental model specificities.

5. The literature has used different terminologies for similar conditions. Leeper (1991) defines 'passive' fiscal policy (as opposed to 'active') as one that raises taxes sharply when public debt increases. Woodford (2001) defines a 'Ricardian' fiscal policy as one that ensures that the intertemporal government budget constraint holds for any given price level and relates this with the 'fiscal requirements' embedded in the Stability and Growth Pact of the Economic and Monetary Union (EMU). More generally this may be ensured by a proper set of 'fiscal rules' (see Blanchard *et al.* 2020).

6. The so-called transversality condition can be rationalised from the optimising behaviour of private agents and asset market clearing conditions, which should prevent the public sector from engaging in Ponzi schemes: $\lim_{T \to \infty} E_t[v_{t,T}(\frac{B_T + M_T}{P_{T+1}})] \leq 0$.

7. In a standard general equilibrium micro-founded model this can be replaced by $v_{t,T} = \beta^{T-t} \frac{u'(c_T)}{u'(c_t)}$, where β is the subjective discount factor and $u'(c_t)$ is the marginal utility of consumption in period t.

Under an optimal behaviour of private agents, condition (2) will hold with equality, so the initial price level or the present discounted value of future primary surpluses and seignorage revenues may need to adjust to satisfy the constraint, if the value of nominal liabilities increases.

This intertemporal budget constraint is often presented in a slightly different version that uses a definition of seignorage revenues as the period increase in real money balances $\sigma_t = \frac{M_t - M_{t-1}}{P_t}$:

$$\frac{B_{t-1}}{P_t} \leq E_t \left[\sum_{T=t}^{\infty} v_{t,T}(\tau_T + \sigma_T) \right] = E_t \left[\sum_{T=t}^{\infty} v_{t,T}(\tau_T) \right] + E_t \left[\sum_{T=t}^{\infty} v_{t,T}(s_T) \right] - \frac{M_{t-1}}{P_t} \quad \text{(2a)}$$

The sum of the last two terms is generally considered the total value of seignorage: the present discounted value of future seignorage revenues minus the initial real money balances. This decomposition clarifies that the central bank may increase total seignorage using two alternative policies. First, it may increase the present discounted value of seignorage revenues, which is typically achieved by raising the long-run level of inflation (e.g. raising the inflation target) and thus the long-run level of the nominal interest rate.[8] Second, the central bank may engineer an increase of the initial price level P_t, thereby reducing the real value of initial money holdings (and also other nominal liabilities).

From an intertemporal perspective, uncertainty around the central bank's ability to sustain a given inflation objective may arise if the present value of future primary surpluses and future seignorage is perceived to be lower than the current level of public sector liabilities. If the public debt increases without a corresponding increase of the present value of future primary surpluses, either the central bank gives in and increases seignorage revenues (and average inflation), or the initial price level needs to adjust.[9] This shows that the ability of a central bank to meet a certain inflation objective crucially hinges on satisfying a condition that is inextricably linked with the conduct of fiscal policy.

In general, condition (2) is compatible with multiple equilibria, i.e. there may exist alternative policies governing the trajectories of the stochastic variables that satisfy this budget constraint. If agents question the willingness or ability of the government to generate sufficiently high primary surpluses in the future to pay the initial level of public debt, the public sector may be vulnerable to expectations-driven debt crises.

8. This positive relation between the nominal interest rate and inflation in the long run follows from the Fisher equation that defines the real interest rate as the difference between the nominal interest rate and inflation ($r_t = i_t - E_t[\pi_{t+1}]$) and from the assumption that the real interest rate in the long run is independent from inflation or the nominal interest rate. We are also assuming that we are on the increasing part of the Laffer curve and hence postulate a positive relationship between inflation and seignorage revenues.

9. The latter is akin to the fiscal theory of the price level (see Cochrane 2022, for a thorough discussion). If, at any moment, public debt holders raise concerns about the verification of this constraint, they may be willing to exchange government bonds and domestic currency for other financial assets (leading to the reduction of the market value of debt) or for goods and services (leading to higher inflation).

Corsetti and Dedola (2016) show that the central bank can eliminate these bad equilibria, by acting as a backstop for government funding, i.e. issuing monetary liabilities in exchange of public debt securities. If risks are not fundamental (i.e. if there are still possible trajectories of primary surpluses, inflation and interest rates compatible with the authorities' objectives that satisfy the budget constraint), such policy actions may reduce the interest rate on public debt and comply with the budget constraint, without generating higher inflation. Arguably, this may have justified at least part of the increase of central banks' balance sheet exposures observed over the past decade.

With the advent of 'independent' central banks tasked with specific objectives (e.g. price and macroeconomic stability) that may conflict with the desires of fiscal authorities, the financial situation of a central bank may affect its ability to fulfil its mandate and complicate monetary-fiscal interactions. Stella (1997, 2002) was one of the first to study the implications of a central bank's financial strength for achieving low and stable inflation. He analysed several episodes of central banks that incurred large capital losses, mainly in emerging and developing economies, and discussed the implications for the conduct of monetary policy. Stella and Lonnberg (2008) examined in further detail the laws governing the financial interaction between central banks and fiscal authorities in a large set of countries and showed that often the fiscal authority leaves the central bank dependent on seignorage to finance their operations, in practice leading to policy insolvency. These findings suggest that it is reasonable to model the two institutions separately.[10]

In a setting where the monetary and fiscal authorities are autonomous institutional bodies, each of them will need to satisfy an independent budget constraint. However, the two budget constraints will still be linked by financial transfers between the two entities. Usually these transfers take the form of dividend payments from the central bank to the Treasury, but in general they could also be negative, if the Treasury recapitalises the central bank. Defining these transfers in real terms as d_t, we have the following flow budget constraint for the fiscal authority

$$B_{t-1}^{G} \leq \frac{1}{1+i_t} B_t^G + P_t \tau_t + P_t d_t \tag{3}$$

and for the central bank[11]

$$M_{t-1} - B_{t-1}^{CB} \leq \frac{1}{1+i_t} \left(M_t - B_t^{CB} \right) + P_t s_t - P_t d_t \tag{4}$$

where B_t^G represents total government issued by the fiscal authority and B_t^{CB} represents government bonds held by the central bank.

10. The implications of this setting are discussed in detail in a recent growing literature. See Bassetto and Messer (2013), Del Negro and Sims (2015), Hall and Reis (2015), or Benigno and Nisticò (2020).

11. For simplicity the budget constraint abstracts from the central bank's administrative costs, as these are typically dwarfed in comparison with seignorage revenues.

Again iterating forward each equation and using similar transversality conditions,[12] one can obtain the following intertemporal budget constraints for the fiscal authority and the central bank, respectively:

$$\frac{B^G_{t-1}}{P_t} \leq E_t\left[\sum_{T=t}^{\infty} v_{t,T}(\tau_T + d_T)\right] \tag{5}$$

$$\frac{M_{t-1} - B^{CB}_{t-1}}{P_t} \leq E_t\left[\sum_{T=t}^{\infty} v_{t,T}(s_T - d_T)\right] \tag{6}$$

The first condition highlights again the need for monetary dominance: if the fiscal authority does not ensure a sustainable fiscal policy, the present value of future central bank's dividends would need to increase, putting pressure on the monetary authority to achieve this through higher seignorage and inflation. Additionally, the second condition suggests that, in certain circumstances, the ability to control inflation may also depend on 'fiscal support', i.e. the existence of a financial transfer from the fiscal authority to guarantee the central bank's solvency ($d_t < 0$). If the fiscal authority is committed to provide fiscal support whenever needed and there is no fiscal dominance, then the central bank is always independently solvent. In practice, this may be implemented with a rule that transfers all central bank's profits – including negative profits – to the fiscal authority. In this case, and using $B_t = B^G_t - B^{CB}_t$, only the consolidated budget constraint (2) will be relevant and monetary policy will be able to independently achieve a certain inflation objective.

Fiscal support mechanisms have not been made explicit in many advanced economies[13] and may be difficult to guarantee in practice. Moreover, if the central bank's profits are usually positive and tend to grow large, the fiscal authority may be tempted to commit to a certain level of public expenditure and be reluctant to accept a negative transfer. Without fiscal support, the possibility of central bank insolvency arises. In this case, the fiscal and monetary authorities will need to satisfy separate budget constraints. We turn next to this case in more detail.

3. Solvency in the case of a single central bank for a single government

In this section we discuss a setting in which an explicit commitment of the fiscal authority to recapitalise the central bank in case of need is not available. In the absence of such mechanism, the central bank will need to satisfy its budget constraint using its own resources.

12. While the transversality condition on private sector's holdings of government debt follows directly from consumers' optimising behaviour, in principle there is nothing ruling out the possibility that the central bank's holdings of the public debt follow an explosive path. In that case, $\lim_{T\to\infty} E_t[v_{t,T}(\frac{B^{CB}_T}{P_{T+1}})]$ could be positive or negative and would show up on the right-hand side of equation (5) and left-hand side of equation (6). However, in the absence of political economy conflicts between the two entities, this position would be immaterial.

13. See Archer and Moser-Boehm (2013) and Bunea *et al.* (2016). See also the discussion in section 5.

3.1. Intertemporal insolvency

From an intertemporal perspective, slightly rearranging (6), the central bank's budget constraint imposes that the present value of future dividends does not exceed the current central bank's net worth (the real value of assets minus liabilities) plus the present value of seignorage revenues:

$$E_t\left[\sum_{T=t}^{\infty} v_{t,T}(d_T)\right] \leq \frac{B_{t-1}^{CB} - M_{t-1}}{P_t} + E_t\left[\sum_{T=t}^{\infty} v_{t,T}(s_T)\right] \tag{6a}$$

In the simple setting discussed thus far, where the central bank's assets include only nominal risk-free bond holdings and liabilities comprise only non-interest bearing money balances, it is virtually impossible to violate this condition. Assuming no fiscal dominance, Bassetto and Messer (2013) and Benigno and Nisticò (2020) show that the central bank's intertemporal constraint is satisfied for any price level under general conditions, if the central bank pays no interest on reserves or, when interest-bearing reserves are introduced, if it holds only short-term assets with the same risk-return characteristics of reserves.

This setting was coined 'old-style central banking' by Hall and Reis (2015), in contrast to the 'new-style central banking' observed since the great financial crisis, where central banks hold large sums of financial assets that may carry considerable risks financed by a significant leverage on interest-bearing reserves. Under this setting, the possibility of central bank insolvency can no longer be completely ruled out.

To understand this, it is instructive to introduce these features explicitly in our setting. Consider that the central bank buys in period t a portfolio of risky financial assets, summarised by A_t, that pays a nominal return ι_{t+1} only observed in period $t+1$. This portfolio may include government bonds and other financial assets that may carry different sources of risk (e.g. interest rate, credit, and exchange rate risk). Consider also that the central bank now issues interest-bearing reserves H_t at discount that pay the same nominal risk-free return of one-period government bonds, i_t. Then, the central bank's budget constraint reads as follows:

$$M_{t-1} + H_{t-1} - (1+\iota_t)A_{t-1} \leq M_t + \frac{1}{1+i_t}H_t - A_t - P_t d_t \tag{4a}$$

Again, iterating forward, we obtain the following intertemporal constraint:

$$E_t\left[\sum_{T=t}^{\infty} v_{t,T}(d_T)\right] \leq \frac{(1+\iota_t)A_{t-1} - M_{t-1} - H_{t-1}}{P_t} + E_t\left[\sum_{T=t}^{\infty} v_{t,T}(s_T)\right] \tag{6b}$$

The right-hand side of this condition gives an upper bound for the central bank's dividend payments. This can be interpreted as the value of the franchise of the central bank. If fiscal support is not available, then a minimal requirement is that the present value of future dividends is not negative, which leads to the following intertemporal solvency condition for the central bank:

$$\frac{(1+\iota_t)A_{t-1}-M_{t-1}-H_{t-1}}{P_t}+E_t\left[\sum_{T=t}^{\infty}v_{t,T}(s_T)\right]\geq 0 \tag{7}$$

The first term of this condition corresponds to the difference between the market value of the central bank's assets and liabilities, a measure of the central bank's net worth in real terms: $N_t^{CB}=\frac{(1+\iota_t)A_{t-1}-M_{t-1}-H_{t-1}}{P_t}$. The second term represents the present value of real seignorage revenues, which is typically positive and large, if monetary policy is credible. Hence, a central bank can be solvent even if its current net worth is negative, as long as the present value of future seignorage is able to cover such position. For a better assessment of the central bank's solvency, we should then adopt a broader measure of net worth that includes this second term. The literature has often called this the central bank's 'comprehensive net worth': $W_t^{CB}=N_t^{CB}+E_t[\sum_{T=t}^{\infty}v_{t,T}(s_T)]$.

Under 'new-style' central banking, the mismatch between the risk of central bank's assets and that of interest-bearing reserves raises the possibility of central bank insolvency. This would arise if losses in the central bank's assets ($\iota_t<0$), arising for instance from a lower market value of long-term bonds or from credit impairments, were so large as to deplete its net worth by more than the present value of seignorage revenues.[14] If agents anticipated such scenario and there existed no mechanism to recapitalise the central bank, then agents could be reluctant to continue holding central bank's liabilities, which could lead to high inflation.

When the source of risk stems only from the duration mismatch between assets and liabilities, the likelihood of intertemporal insolvency is small. The simulations presented by Del Negro and Sims (2015) suggest that this investment strategy typically provides a sort of natural hedging. Shocks that reduce the real value of the central bank's assets (higher long-term interest rates, if the central bank's portfolio has a long duration) tend to be positively related with inflation expectations and hence may be accompanied by an increase of the present value of seignorage revenues.

The prospect of intertemporal insolvency increases if it involves a shock that reduces net worth without sufficiently increasing future seignorage. This may arise if the central bank's financial assets carry non-diversified credit risk, for instance.[15] This kind of exposure is arguably more prone to jumps that may have an abrupt negative impact on net worth, while being less directly related with the business cycle and inflation and thus having no compensating effect on the present value of seignorage.

Del Negro and Sims (2015) offer another interesting possibility. They describe the effects of introducing 'inflation scares' as defined by Goodfriend (1993), i.e. shocks to

14. As central banks' assets are typically held to maturity, these are often booked at nominal value or amortised cost in the financial statements. Nonetheless, from an economic perspective, the market value is still the relevant metric. Considering the case of duration mismatch, even if an increase in interest rates does not directly affect the book value of fixed-rate long-term assets, it will still lead to losses if the financing cost increases sufficiently.

15. The early example of the Bank of Amsterdam in the 18th century discussed by Quinn and Roberds (2016) is an interesting case in point, as the Bank's losses mainly resulted from the large concentration of investments in the Dutch East India Company, a large government-sponsored enterprise that became insolvent.

inflation expectations that have a positive impact on long-term nominal interest rates without affecting the central bank's inflation objective. These shocks reduce the market value of central bank's assets ($\iota_t < 0$) without major implications on the present value of seignorage revenues. If the effect is large enough, it would require either a capital injection or higher inflation. The latter would confirm agents' inflation scare, opening the door to the existence of multiple self-fulfilling equilibria. As discussed above, the central bank's credibility is crucial to eliminate such equilibria.

3.2. *Alternative definitions of central banks' insolvency*

The last example suggests that there can be uncertainty regarding the verification of the intertemporal budget constraint. Moreover, it is also possible that the central bank's shareholders demand a certain level of positive dividends that may imply the verification of other more stringent conditions of a central bank's solvency.

Reis (2015) proposes two alternative, more restrictive, definitions of central bank solvency that result from different institutional arrangements between the central bank and the fiscal authority. First, 'period insolvency' assumes an extreme lack of fiscal support where the fiscal authority refuses to compensate, now or in the future, any losses of the central bank. This would imply that the central bank would become insolvent as soon as it posts a negative profit. Hence, in order to remain solvent under this definition, the central bank would need to post positive profits ψ_t in every period: $\psi_T > 0, \forall_{T \geq t}$.

Second, 'rules insolvency' would be an intermediate case that relies on the central bank staying committed to the dividend distribution rule foreseen in its relationship with the Treasury. This would be equivalent to period insolvency if the rule implied that dividends could never be negative and that profits could not be used to offset previous losses. But it would be equivalent to intertemporal insolvency if the rule allowed to build a deferred account of accumulated losses – to be compensated by future profits –, up to the level of the central bank's comprehensive net worth. Hall and Reis (2015) discuss how a measure of 'rules insolvency' may differ depending on the dividend distribution policies or the accounting principles followed by the central bank.

3.3. *Quantitative assessment of central banks' solvency in advanced economies*

The principles laid out above suggest that the central bank's net worth may not be the best metric to assess the likelihood of insolvency, especially if there is a substantial risk-return mismatch between assets and liabilities. Under 'new-style' central banking, this mismatch has increased significantly, as shown in Figure 2 above. While this increases the likelihood of central banks posting losses, leaving them vulnerable to a negative net worth position, the intertemporal solvency of any central bank may still be solid if the present value of seignorage revenues more than compensates a potentially negative net worth.

The literature has attempted to estimate this component of central banks' comprehensive net worth. Most estimates tend to be large, suggesting a small likelihood of insolvency, but results differ substantially depending on model specifications. Table 1 reports a sub-sample of those estimates:

(All values as percentage of GDP)	Country (scenario)	**Total seignorage**	**Comprehensive net worth (2021)**	*p.m. Total CB's assets (2021)*
Del Negro and Sims (2015)	US (baseline)	114	127	38
	US (higher rates)	18	29	38
Reis (2016)	US (market-based)	33	42	38
	US (historical)	14	23	38
Buiter and Rahbari (2012)	US	21	30	38
	Euro area	40	59	70
	Japan	40	65	134
	UK	11	15	49

TABLE 1. Estimates of central banks' comprehensive net worth found in the literature

Notes: Most of these papers only present estimates for the value of total seignorage: $E_t[\sum_{T=t}^{\infty} v_{t,T}(\sigma_T)] = E_t[\sum_{T=t}^{\infty} v_{t,T}(s_T)] - \frac{M_{t-1}}{P_t}$. As comprehensive net worth is given by $W_t^{CB} = N_t^{CB} + E_t[\sum_{T=t}^{\infty} v_{t,T}(s_T)]$, we can proxy it by adding reported equity and currency in circulation to the estimated value of total seignorage. The table reports W_t^{CB} using currency in circulation and equity reported for the end of 2021, except for Del Negro and Sims (2015), who directly report a measure of comprehensive net worth for their calibration of the US economy. Reis (2016) reports estimates for a number of alternative model settings and discount rates; this table reports the upper and lower bounds of those estimates. Buiter and Rahbari (2012) provide estimates of the value of total seignorage for alternative steady state levels of the nominal discount rate and GDP growth rate; this table reports estimates using 4% and 1.5%, respectively.

In the table, the estimate provided by Del Negro and Sims (2015) in their baseline calibration of a general equilibrium model for the US economy stands out, as they report an estimate of comprehensive net worth that is a multiple of the level of the central bank's assets. This is mainly the result of considering a very low discount rate of 0.25%. Still, even under higher discount rates, and taking into account uncertainty around seignorage revenues, as in Reis (2016), alternative estimates for the US economy point to a level of comprehensive net worth that is of the same order of magnitude of the current historically high level of total central banks' assets. Buiter and Rahbari (2012) provide estimates for other central banks and reach similar conclusions. This means that, from an intertemporal perspective, central banks would be able to cope with a very substantial negative shock on the market value of its assets, without the need for recapitalisation.[16]

These estimates suffer from a number of limitations. First, they are very sensitive to assumptions on the discount rate, which is reflected in the range of estimates presented for the US.[17] Second, they depend significantly on the relationship between inflation and seignorage. Similarly to other taxes, the real seignorage revenues may be subject to a Laffer curve, meaning that above some level higher inflation actually implies a reduction of seignorage revenues. Third, estimates also depend crucially on money demand functions, which may be on the verge of a structural change, given increased

16. The difference between comprehensive net worth and the total value of seignorage (in columns 4 and 3 of Table 1) gives a measure of net worth plus currency in circulation. The fact that this is significantly lower in the cases of the US, and especially the UK, reflects the different mechanisms put in place to offset any potential losses. See discussion in section 5.

17. See also the sensitivity analysis provided by Buiter and Rahbari (2012) for other countries.

competition from external alternatives and the possible introduction of central bank digital currencies. Still, the more conservative estimates suggest that the likelihood of intertemporal insolvency in any of these economies is very small.

Hall and Reis (2015) assess alternative more stringent metrics of central banks' solvency that take into consideration the accounting standards and dividend policies of three major central banks. They characterise the main sources of risk for the Federal Reserve (interest rate risk), the Eurosystem (sovereign credit risk) and the Swiss National Bank (exchange-rate risk) and find that in most adverse scenarios these central banks would be able to avoid high inflation and continue paying dividends in most periods. In the case of the US, Carpenter *et al.* (2015) and more recently Cavallo *et al.* (2019) simulate the effect of different scenarios for the Federal Reserve's normalisation policies on net income and remittances to the Treasury and find that the likelihood of an accumulation of substantial losses is extremely remote. While these estimates were obtained before the most recent increase of central banks' balance sheets size and exposures, they still seem to suggest that the financial situation of central banks in advanced economies is sufficiently strong to cope with large shocks.

4. The case of a monetary union

The existing literature has mainly focused on the case of a single monetary authority issuing liabilities in domestic currency. While many of the conclusions obtained from such setting can be extended to the case of a monetary union, this environment raises additional challenges that deserve a careful discussion. As monetary policy is decided at the aggregate level and does not depend on the idiosyncratic decision of a single national authority, one may be led to conclude that the independence of monetary policy with respect to any potential external pressures is higher in a monetary union. Nonetheless, understanding the complex web of interactions between NCB within the system and with each national fiscal authority is important, in particular whether concerns on the financial situation of a national fiscal authority or a NCB may have implications to the aggregate level.

The first important question is on how to ensure the conditions for 'monetary dominance' and 'fiscal support' in a monetary union. Sims (1999) was probably one of the first to highlight some of the difficulties that this institutional arrangement could entail, focusing on the specific case of the EMU. In what regards monetary dominance, he speculated that the commitment to fiscal rules on the part of several fiscal authorities would be feeble, which could lead to fiscal free-riding and financial stress in some countries that could threaten the EMU credibility.

Bergin (2000) was another early contribution. He showed that, in the absence of a mechanism that ensured monetary dominance, an unsustainable fiscal policy in a single country could lead to a higher price level in the currency area. On a more positive note, he also showed that monetary dominance could be achieved under different policy arrangements. One common proposal would be for each national government to ensure its own public debt sustainability, which provides some justification for the fiscal restrictions foreseen in the EMU's Stability and Growth Pact. But, more generally, monetary dominance could be guaranteed by a central fiscal authority defining national fiscal policies under a commonly agreed framework, or even by any national government taking actions at the national level to ensure public debt sustainability at the aggregate level. However, the latter arrangement could result in diverging paths for national public debt levels, which would probably raise questions on the stability of the monetary union.

In what regards the fiscal support condition, this could also be envisaged under centralised or decentralised arrangements. But, in the absence of an explicit mechanism, fears of capital losses could limit NCB's actions. Corsetti *et al.* (2019) discuss the need for coordinated stabilisation policy in the context of the EMU, supporting the role of the central bank as a lender of last resort and backstop for government funding. As discussed above, the central bank's actions under these roles may eliminate non-fundamental self-fulfilling equilibria and from that perspective be themselves crucial to control inflation expectations.[18] However, they typically imply assuming higher financial risks. In order to ensure the central bank's ability to accomplish these endeavours without endangering the price stability objective, the authors propose some institutional changes to the euro area, including the need for fiscal support of the Eurosystem at the aggregate level.

In the absence of explicit fiscal support, there is the need to satisfy a solvency condition like (7) at the aggregate level. Moreover, if there is limited risk sharing within the monetary system, each NCB will need to satisfy a separate budget constraint. An immediate application of condition (7) suggests that a NCB's solvency will depend on its own net worth and its share in the present value of future seignorage revenues, but this conclusion abstracts from potential financial linkages between the different NCB.

Bassetto and Caracciolo (2021) have recently formalised this setting, suggesting that the solvency of each NCB is important to sustain the credibility of the common monetary policy. Even if a large capital loss of an individual NCB does not threat the aggregate solvency condition, if there were no fiscal support from the national fiscal authority, the loss would be eventually covered by the whole system. This could imply either an implicit transfer of resources between members of the monetary system or the acceptance of higher seignorage revenues (and inflation).[19] In this context, ensuring the solvency of each NCB may be important to guarantee an ecosystem of mutual trust within a common monetary system that preserves the credibility of monetary

18. See Cardoso da Costa and Gomes (2021).

19. In the case of the Eurosystem, this would contradict Article 125 of the EU Treaty. Buiter (2020) discusses the specific case of the Eurosystem, stressing the risk of insolvency for NCB stemming from the non-shared exposure to own government default risk. In such circumstances, it is unlikely that the national fiscal authority would be able to provide fiscal support, which increases the risk of spilling over to the Eurosystem as a whole.

policy.[20] A formal discussion of the setting developed by Bassetto and Caracciolo (2021) is presented in an Appendix.

5. Mechanisms to support central bank solvency

The previous sections present a theoretical framework that helps us understand the financial boundary of central banks' actions. In the absence of a credible mechanism of fiscal support, it remains in the central bank's hands the ability to ensure its own solvency. The literature has discussed different mechanisms to minimise the likelihood of policy insolvency, often building on the institutional arrangements observed in practice.

Sims (2004) suggests that central banks should diversify their portfolio of assets and invest in sound and stable entities, while building up net worth (i.e. capital buffers) through retained earnings.[21] Similarly, Goodfriend (2014) suggests that central banks with large long-duration balance sheets should avoid the carry trade and retain part of their income in the beginning of a quantitative easing process to hedge against financial risks that may materialise when policy rates start to increase. Hall and Reis (2015) discuss the use of deferred assets, whereby central banks losses would be offset by future profits. The authors also suggest other risk management mechanisms that may be useful for specific exposures, such as mark-to-market accounting and repurchase agreements (in case of exposure to default risk) or exchange rate pegs (in case of exposure to foreign currency risk). Finally, Reis (2015) discusses examples of central banks that segregate part of their financial investments in specific facilities to shield the balance sheet from any potential losses. If the fiscal authority fully indemnifies these facilities, it is providing an explicit mechanism of fiscal support for the risks associated with that specific portfolio.[22]

Having this said, reviewing the institutional arrangements observed in the major advanced economies is instructive, as they cover a large spectrum of the mechanisms proposed in the literature.

5.1. Institutional arrangements in major advanced economies

The Federal Reserve System relies mainly on the establishment of deferred assets. Under the Federal Reserve's accounting standards, when earnings are insufficient to cover the operational costs, thus implying a net income loss, remittances to the Treasury are

20. In the case of the EMU, the Agreement on Net Financial Assets, which has been set up to limit the impact of decisions unrelated with monetary policy on the aggregate balance sheet, may also serve as a mechanism to minimise the likelihood of such negative spillovers.

21. At the same time, the author cautions that building large financial buffers may also put pressure on the central bank's independence, as it may raise political pressure to use accumulated reserves. Moreover, the central bank may also be tempted to enlarge its mission to justify the maintenance of additional buffers, exposing the bank to other risks.

22. This arrangement may be less credible if such facility is particularly exposed to sovereign credit risk, which is yet another reminder that the condition of monetary dominance remains necessary.

suspended until cumulative earnings are sufficient to cover the losses accumulated in the deferred asset account.[23] The 'deferred asset' is booked as a negative liability, thus insulating the central bank's capital. This arrangement, if credible and applied with no limit, would in fact satisfy a full fiscal support mechanism from an intertemporal perspective. However, as Carpenter *et al.* (2015) note, there has never been a deferred asset of significant size, so there is no guidance on how large that limit could be. The accounting standards provide that deferred assets should be periodically reviewed for impairment, which suggests that the limit may be lower than the present value of future seignorage. Nonetheless, the simulations of Hall and Reis (2015) and Carpenter *et al.* (2015) suggest that the accumulation of losses resulting in a very large deferred asset would be extremely unlikely.

The Bank of England currently has two complementary mechanisms that provide substantial fiscal support, without the need to rely on a large capital buffer. On one hand, the Bank established in 2009 the 'Bank of England Asset Purchase Facility Fund', which holds all asset purchases conducted for monetary policy purposes and is fully indemnified by the HM Treasury. In February 2021 the loan to this Facility represented more than 80% of the central bank's assets, which significantly dwarfs the central bank's unbacked exposures. On the other hand, in 2018 the Bank of England and the HM Treasury agreed on a new framework for the central bank's capital, establishing a target, a floor and a ceiling for the level of loss-absorbing capital, that serve of reference to determine the proportion of earnings to be distributed. If the Bank's capital falls below the floor, the HM Treasury is mandated to recapitalise the Bank in an amount that brings the level back to target. Otherwise, the Bank of England may or may not pay dividends, depending on the comparison with the target and the ceiling.[24]

Finally, the Bank of Japan and the Eurosystem mainly rely on building financial buffers to pre-emptively ensure sufficient capital to cover any potential losses. This may be done through different mechanisms: (i) retaining part of net profits as capital or reserves; (ii) building financial provisions for specific or general purposes;[25] or (iii) maintaining revaluation accounts for unrealised capital gains.[26] In the case of the Eurosystem, these three layers of financial buffers serve as different lines of defence of the ECB's and NCB's net worth against possible losses. Revaluation accounts are

23. See Federal Reserve Board (2022), p. 56.

24. See HM Treasury (2018). Since the implementation of this memorandum of understanding, the Bank of England was recapitalised in 2019 and did not pay dividends to the Treasury in 2021 nor in 2022.

25. The Bank of Japan has separate provisions for possible losses in bond transactions and foreign exchange transactions, for example. Within the Eurosystem the capital policy followed by De Nederlandsche Bank since 2019 is a good example of how different financial buffers may be built for different purposes. In the 2019 Annual Report, the DNB draws a clear "distinction between buffers to cover temporary risks (the provision for financial risks) and buffers to cover structural and hidden risks (capital)". See De Nederlandsche Bank (2020).

26. In the case of the Eurosystem, unrealised capital gains/losses have an asymmetric accounting treatment: gains are used to build revaluation accounts that show up as a positive liability in the balance sheet, while losses may have an impact on earnings (and hence capital), if they surpass the respective revaluation account.

reduced first, if and only if part of the unrealised gains are reversed. Additional losses may be covered by a reduction of financial provisions (if available), or may directly affect earnings and capital.

Over the past decade, financial buffers in the Eurosystem increased significantly, mainly driven by the evolution of revaluation accounts related with the market value of gold reserves. Excluding this component, however, financial buffers still increased at a higher pace than nominal GDP, especially through the build up of financial provisions since the great financial crisis, accompanying part of the increase of balance sheet size and exposures. This evolution has been broad-based across NCB, but the level of financial buffers still reveals substantial heterogeneity within the Eurosystem that may reflect different balance sheet exposures, but also different mechanisms regarding the relationship between the monetary and fiscal authorities at the national level, namely in what regards dividend distribution policies.

6. Concluding remarks

This synopsis discusses the financial boundaries of central banks' actions. The literature has developed an appropriate theoretical framework that clarifies the importance of this discussion and shows that it lays at the core of the interactions between monetary and fiscal policies. In order to ensure that the central bank has the power to sustain an inflation objective, the fiscal authority needs to guarantee public debt sustainability and should also be ready to provide fiscal support to the central bank in case of need. In the absence of the latter, the central bank needs to satisfy an autonomous solvency condition.

The current sizeable exposure of central banks' balance sheets in advanced economies, especially vulnerable to interest rate and non-diversified sovereign credit risk, leave them susceptible to incur some losses. These exposures result from policies that may have contributed to eliminate non-fundamental self-fulfilling equilibria and hence do not necessarily pose a fundamental threat of insolvency from an intertemporal perspective. While policy decisions going forward should not be contaminated by concerns over potential short-term losses, it is crucial that the institutional framework (including central banks' accounting policies and rules governing the distribution of dividends or the need of capital injections) guarantees the pursuit of fiscal and monetary policies that avoid any fundamental concerns.

The evidence suggests that the possibility of policy insolvency of central banks in advanced economies is extremely unlikely. Nonetheless, history showed that abnormal unexpected events occur, so it is paramount to continue enforcing the necessary mechanisms to ensure that such episodes remain only in the realm of a theoretical possibility. Maintaining an active and transparent debate about these issues contributes to the understanding of how to properly design such mechanisms.

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Appendix: Budget constraint of a NCB in a monetary union and possible implications for monetary policy

In a recent effort to understand the implications of a central bank's solvency for the credibility of monetary policy within a monetary union, Bassetto and Caracciolo (2021) define separate budget constraints for each national fiscal authority and each NCB. Focusing on the budget constraint of an individual NCB, the main difference with respect to condition (6b) in the main text, is that now we need to consider the possibility of financial linkages (claims and liabilities) between members of the monetary system.[27] We define X_t^n as the intra-union claims (liabilities) of the NCB of country n with respect to the other members of the system whenever $X_t^n > 0 (< 0)$. Assuming that these positions are issued at discount with a nominal interest rate i_t, just like common interest-bearing reserves, and that they exist in zero net supply ($\sum_n X_t^n = 0$), the flow budget constraint for the NCB of country n can be written as:

$$M_{t-1}^n + H_{t-1}^n - X_{t-1}^n - (1+\iota_t^n)A_{t-1}^n \leq M_t^n + \frac{1}{1+i_t}(H_t^n - X_t^n) - A_t^n - P_t d_t^n \tag{A.1}$$

Then, following directly Bassetto and Caracciolo (2021), the intertemporal budget constraint of NCB of country n can be written as:

$$\begin{aligned} E_t\left[\sum_{T=t}^{\infty} \upsilon_{t,T}(d_T^n)\right] \leq \frac{(1+\iota_t^n)A_{t-1}^n + X_{t-1}^n - H_{t-1}^n - M_{t-1}^n}{P_t} + E_t\left[\sum_{T=t}^{\infty} \upsilon_{t,T}(s_T^n)\right] - \\ - \lim_{T\to\infty} E_t\left[\upsilon_{t,T}\frac{X_T^n}{P_{T+1}}\right] \end{aligned} \tag{A.2}$$

The main difference with respect to condition (6b) is the presence of intra-union positions, which show up in the initial net worth and also in the final limiting term. The presence in the initial net worth is immaterial, given the assumption that these claims pay the same interest as reserves. Some NCB may issue reserves that are then used to purchase assets by a second NCB in a different jurisdiction, which would imply that the former NCB would hold an intra-union claim over the system, while the latter would have a liability. It is only relevant the level of interest-bearing liabilities net of these positions: $(H_{t-1}^n - X_{t-1}^n)$.

27. In the Eurosystem these claims and liabilities are mainly reflected in the TARGET positions of each NCB vis-à-vis the ECB that serves as the direct counterpart (i.e. the positions are not directly defined between any two NCB, but between each NCB and the ECB). These balances increased significantly during the global financial crisis, as the money market dried up and the Eurosystem stepped in to intermediate funding between commercial banks, often from different jurisdictions. Balances also increased significantly with the implementation of large-scale asset purchases since 2015, as often NCB buy securities held by foreign investors. In either case, the increase of these balances resulted from the regular functioning of monetary policy, simply reflecting the fact that the reserves issued by one NCB may be used to finance commercial banks of a different jurisdiction. For a primal explanation, see: https://www.ecb.europa.eu/ecb/educational/explainers/tell-me-more/html/target2_balances.en.html.

The final term is more interesting (and controversial). The presence of this term reflects the possibility of an explosive path on the intra-union positions, with one NCB constantly rolling over an ever-increasing liability vis-à-vis the monetary system ($\lim_{T\to\infty} E_t\left[v_{t,T}\frac{X_T^n}{P_{T+1}}\right] < 0$), which would imply that some other NCB would accept maintaining an ever-increasing intra-union claim ($\lim_{T\to\infty} E_t\left[v_{t,T}\frac{X_T^n}{P_{T+1}}\right] > 0$). As discussed in the main text, typically these diverging paths are excluded by the assumption of some transversality condition that can be rationalised from the optimising behaviour of the agent that would hold these positions: a private household would always prefer to increase consumption than to accumulate ever-increasing assets. Bassetto and Caracciolo (2021), however, argue that the same reasoning cannot be applied between two NCB, as these entities are not maximising consumption and thus nothing prevents them from accumulating exploding amounts of financial claims.

The presence of this term would mean that it would be straightforward for any individual NCB to satisfy its intertemporal constraint, an apparent symptom of the irrelevance of NCB solvency. But it also would mean that, under some equilibria, the constraint of other NCB would be affected. In particular, the creditor NCB would either need to accept a reduction in the present value of dividends to be paid to its national authority, or accept a higher inflation to generate a proportional increase of seignorage revenues. Hence, under this setting, the credibility of the common monetary policy could be affected by the materialisation of risks in an individual NCB.

However, the possibility of equilibria with such diverging paths of intra-union positions, which would effectively imply a transfer between two jurisdictions, is not consensual in the literature. For instance, Bergin (2000) has discussed the possibility of equilibria with explosive paths of government bond holdings across different fiscal authorities, but these equilibria have been considered unappealing, as they would imply a welfare loss of the individuals in the country whose government would accept to hold such positive positions.

The same reasoning could be used to rule out the equilibria with diverging paths of intra-union positions within a monetary system. Most likely, such equilibria would be difficult to sustain politically. Nonetheless, it is instructive to understand the potential implications of a capital loss in an individual NCB.