1 The Central Bank Balance Sheet: Why It Matters

1.1 THE POST–GREAT FINANCIAL CRISIS CENTRAL BANK BALANCE SHEET EXPLOSION

The size of central bank balance sheets in many advanced economies has increased massively since the start of the Great Financial Crisis (GFC) in the second half of 2007.[1] Even before central bank policy rates hit the effective lower bound (ELB), there were significant balance sheet increases due to the lender-of-last-resort (LLR) and market-maker-of-last-resort (MMLR) operations of the Fed, the Bank of England and the ECB. Figures 1.1 through 1.6 tell the story.

Once the policy rate (generally a short, risk-free nominal interest rate) hit the ELB, and the authorities were unable or unwilling to eliminate or materially lower the ELB, there were only three options open to the monetary policy makers. The first was to change the size and composition of the balance sheet. The second was "open mouth operations," including forward guidance about policy rates and the size and composition of the balance sheet. The third was to target some other financial asset price, like a long-term interest rate or the exchange rate.[2] Of the major monetary authorities, only the Japanese chose the third option when the Bank of Japan (BoJ) introduced "Quantitative and Qualitative Monetary Easing with Yield Curve Control" in September 2016. It pegged the overnight rate (the

1 GFC is often expanded as *Global* Financial Crisis. This is inaccurate; the financial crisis was confined to the North Atlantic region; hence our preference for *Great* Financial Crisis.

2 In a Modigliani–Miller world in which the relative supplies of different nonmonetary assets do not affect yields, credible forward guidance about the (short) policy rate would also pin down longer-maturity rates (over the horizon of the forward guidance). Term premia can, of course, be present even in a Modigliani–Miller world.

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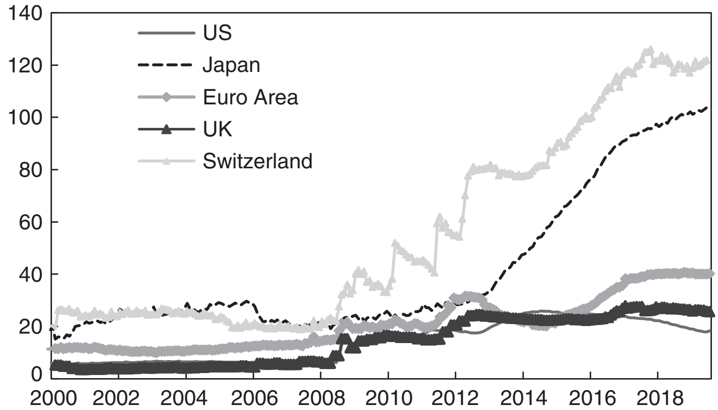

FIGURE 1.1 Central bank assets

uncollateralized overnight call rate) at –10bps and targeted the ten-year Japanese Government Bond (JGB) yield at close to zero (strictly a target range between 0 percent and 10bps), which meant that the size of the Bank of Japan's purchases of longer-dated sovereign debt became endogenous.[3]

The Fed's balance sheet as a share of GDP was 5.98 percent at the end of June 2007. It peaked as a share of GDP at the end of 2014 at 25.81 percent. At the end of June 2018, it was 21.09 percent. The decline since the end of 2014 reflects the growth of nominal GDP, the tapering that started in December 2013, followed by the end of QE on October 29, 2014, and the start of quantitative tightening (QT) or balance sheet shrinking) in October 2017, which ended in August 2019.

The Bank of England had a balance sheet equal to 6.38 percent of GDP in February 2008. This grew to 24.14 percent of GDP in February 2013, fluctuated a little and reached 24.4 percent of GDP at the

[3] The ten-year JBG target was changed on July 31, 2018, to a target range between 0 percent and 20bps. The BoJ could, in principle, set both price and quantity in the JGB market by choosing a "rationing equilibrium" that is not on the market supply curve of JGBs – specifically an equilibrium where at the pegged JGB yield the quantity bought by the BoJ is less than the quantity offered by the market. We don't think this is how the yield curve control is implemented.

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beginning of 2017. It appears to have remained roughly constant in nominal terms since then, with the ratio to GDP declining gently as nominal GDP continued to increase. The balance sheet of the consolidated Eurosystem was 12.85 percent of Eurozone GDP at the end of June 2007. It stopped expanding in nominal terms with the end of the first QE programme in December 2018. The Eurosystem actually shrank its balance sheet by around €1 tn between June 2012 and November 2014. Its balance sheet peaked as a share of GDP at 40.04 percent at the end of 2017, a level from which it declined very gently since then despite continued balance sheet expansion until December 2018, because of growth in nominal GDP. QE was set to resume at a rate of €20 bn a month in November 2019.

The Bank of Japan's balance sheet was 18.82 percent of GDP in June 2007. At the end of June 2018 this had risen to 96.60 percent and it can be expected to rise further if the Bank of Japan succeeds in hitting its current quantitative and qualitative easing plans (¥80 tn at an annual rate) or manages to continue its (lower) actual volume of asset purchases (¥ 40 to ¥50 tn at an annual rate).

The balance sheet of the Swiss National Bank was 18.99 percent of GDP in June 2007. Largely driven by foreign currency inflows, it now stands at 120.72 percent of GDP (June 30, 2018).

Among the advanced economies, New Zealand, Denmark, Norway, Australia and Canada stand out by having no material increases in the size of their central banks' balance sheets as a share of GDP since the GFC.

Some details about the composition of the assets and liabilities of the Fed can be found in Figures 1.2a and 1.2b.

In the United States, on the asset side of the balance sheet, the initial explosion involved "other assets," reflecting emergency asset purchases and collateralized lending operations during the initial panic phase of the GFC. Such LLR and MMLR operations were no longer as significant when financial chaos had been subdued in 2010. Since then, mortgage-backed securities (MBS) and Treasury debt have

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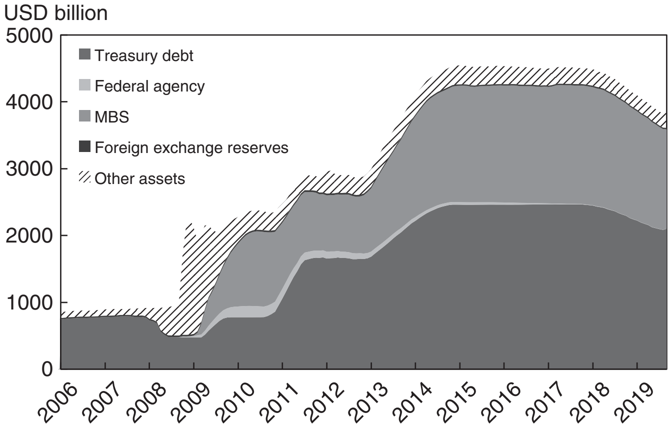

FIGURE 1.2A US Federal Reserve assets

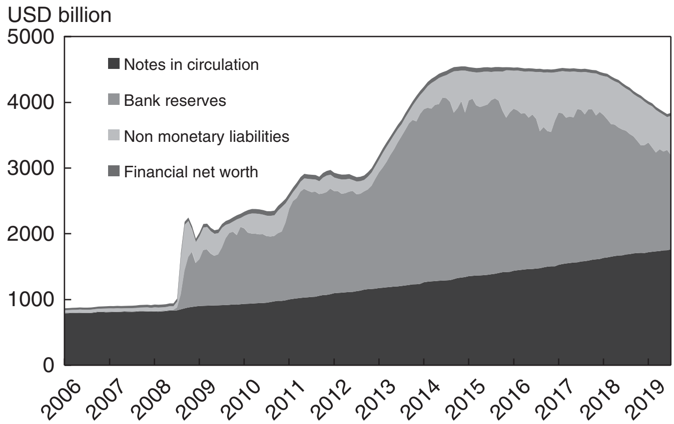

FIGURE 1.2B US Federal Reserve liabilities

accounted for effectively all of the balance sheet expansion on the asset side, and the shrinkage, since October 2017.

On the liability side of the Fed's balance sheet, the explosion in excess reserves since 2008 is a familiar story. What is perhaps more surprising is that the stock of currency (notes in circulation) more than doubled from \$811 bn to \$1,661 bn between June 2007 and June 2018. US population in 2018 is about 326.8 million, so there is just

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over $5,000 of currency outstanding for every man, woman and child in the United States. Rogoff (2016, 2018) estimates that around 44 percent of the stock of US currency (by value) is held abroad, but that still leaves more than $2,800 in cash for each US resident. This suggests that cash holdings in the United States are distributed highly unevenly, with the anonymity of cash making it a favorite store of value and medium of exchange for illegal activities.

The recent growth in the size of nonmonetary liabilities reflects continued attempts by the Fed to move its practices for managing the size and composition of its balance sheet into the twenty-first century, for instance by using reverse repos (called repos outside the USA) which include nonbank counterparties, something that is clearly sensible in a country where banks account for only just over 30 percent of financial intermediation (see Financial Stability Board (2018)).[4]

The US Treasury, like any central government Treasury or ministry of finance, is the beneficial owner of the central bank, regardless of the often rather esoteric formal ownership arrangements history may have bestowed on the central bank. That means the US Treasury receives something akin to the "profits" of the Federal Reserve System – and has a material role in determining how such profits are

4 The New York Fed conducts overnight reverse repo operations each day as a means to help keep the federal funds rate above the floor of the target range set by the Federal Open Market Committee (FOMC). An overnight reverse repurchase agreement (ON RRP) is overnight secured borrowing by the Fed from eligible counterparties. When the Fed conducts an ON RRP, it borrows overnight in a secured manner by selling a security to an eligible counterparty and simultaneously agreeing to buy the security back the next day at a price set today. There is a reduction in reserve balances on the liability side of the Federal Reserve's balance sheet and a corresponding increase in reverse repo obligations while the trade is outstanding. The FOMC sets the ON RRP offering rate, which is the maximum interest rate the Federal Reserve is willing to pay in an ON RRP operation; the actual interest rate that a counterparty receives is determined through an auction process. It is a complement to the interest rate on excess reserves as an instrument for setting a floor on the overnight market rate. In a Fed overnight repo (called a reverse repo outside the USA) it buys a security from an eligible counterparty and simultaneously agrees to sell the security back the next day at a price set today. It amounts to a secured overnight lending rate for the Fed. In principle, the overnight repurchase operations could be used to keep the overnight market rate below the ceiling of the Fed's federal funds target rate. See Board of Governors of the Federal Reserve System, Policy Tools, Overnight Reverse Repurchase Agreement Facility; www.federalreserve.gov/monetarypolicy/overnight-reverse-repurchase-agreements.htm.

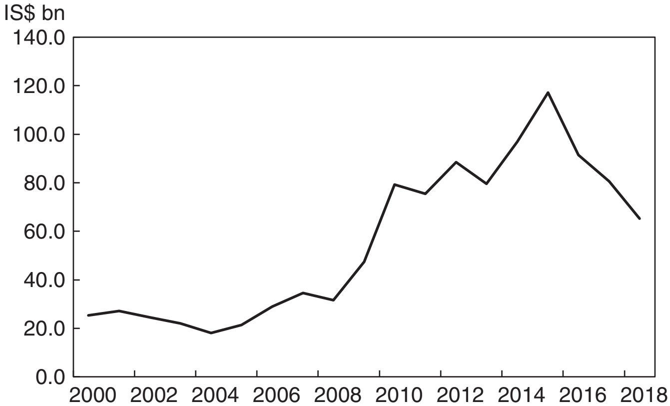

FIGURE 1.3 Fed payments to US Treasury

defined and measured. As shown in Figure 1.3, in the years prior to the GFC, profit remittances from the Fed to the Treasury ranged between $20 bn and $40 bn. They peaked in 2015 (paid in 2016) at $97.7 bn. The decline since 2015 is mostly due to the Fed paying interest on excess reserves (and on required reserves) at a quite generous level, currently (September 19, 2019), 1.80 percent.

Not satisfied with a mere $97.7 bn, Congress in late 2015 raided the reserves of the Regional Reserve Banks to the tune of $19.3 bn to help fund the Fixing America's Surface Transportation (FAST) Act. The 2017 FRB payment to the US Treasury was $80.6 bn and the 2018 payment $65.3bn.

The evolution of central bank assets and liabilities since the GFC for the United Kingdom, the Eurozone and Japan are shown in, respectively, Figures 1.4a,b, 1.5a,b, and 1.6a,b.

1.2 A LITTLE SEIGNIORAGE ARITHMETIC

To put some analytical structure on these expanding central bank balance sheets, and especially on the fiscal and quasi-fiscal implications, the concept of seigniorage is indispensable. Seigniorage is the stream of profits earned by the central bank through its ability to issue base money at negligible marginal cost. It is a key driver of the

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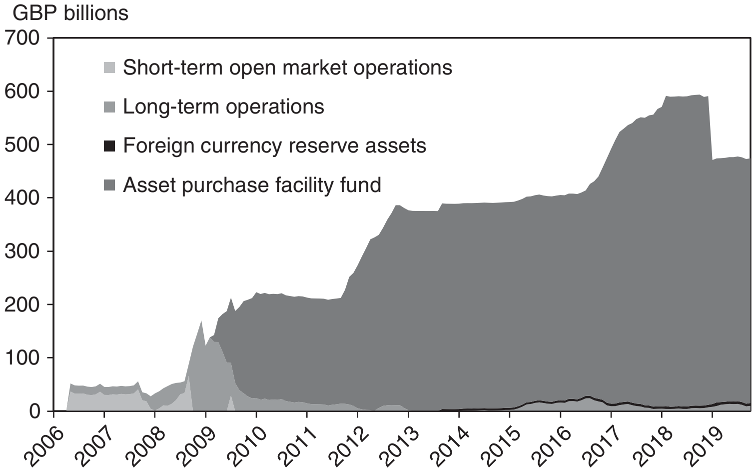

FIGURE 1.4A UK BoE assets

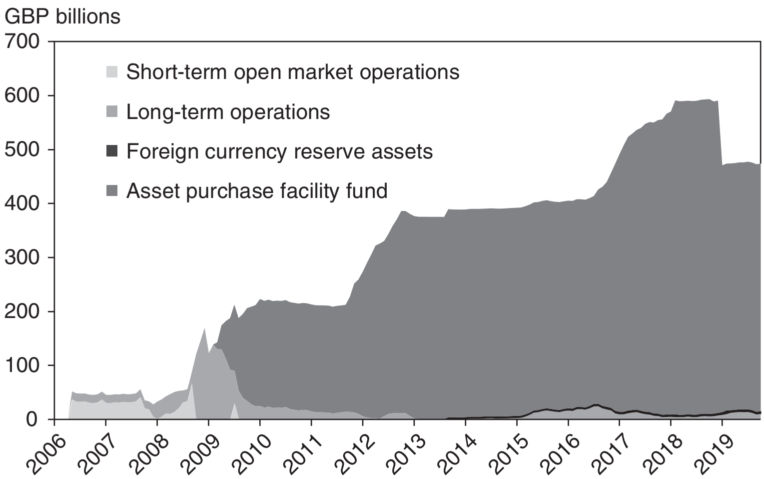

FIGURE 1.4B UK BoE liabilities

contribution of the central bank to the sovereign's funding needs. What follows relies on Buiter (2003, 2007a and 2014a).

In a modern fiat money economy, base money, M, is the sum of the stock of currency, J, and commercial bank reserves held with the central bank, Z, itself the sum of required reserves, Z^r, and excess

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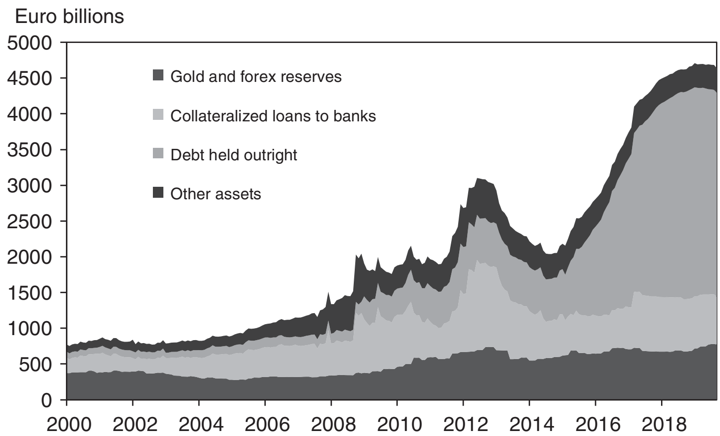

FIGURE 1.5A Eurosystem assets

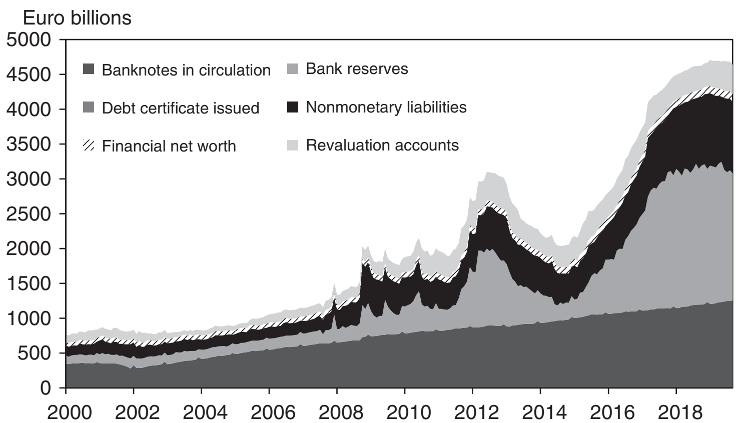

FIGURE 1.5B Eurosystem liabilities

reserves, Z^e. All three components pay interest rates that are typically below the risk-free market rate of interest, $i_{t,t-1}$, the interest rate on one-period safe government debt paid in period t. Currency typically pays a zero interest rate, $i^J_{t,t-1} = 0$. The interest rate on required reserves, $i^r_{t,t-1}$, and on excess reserves, $i^e_{t,t-1}$ are set by the central bank. In addition, currency is *irredeemable* – the holder of a given amount of currency has no other claim on the issuer (the central bank) than for that same amount of currency. For all practical purposes, the

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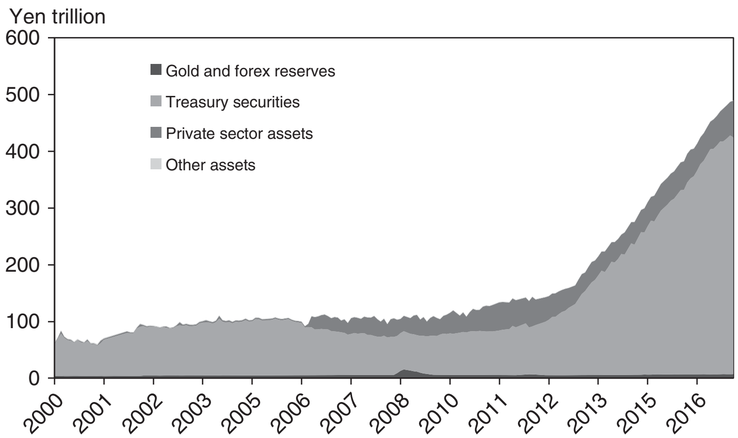

FIGURE 1.6A Japan BoJ assets

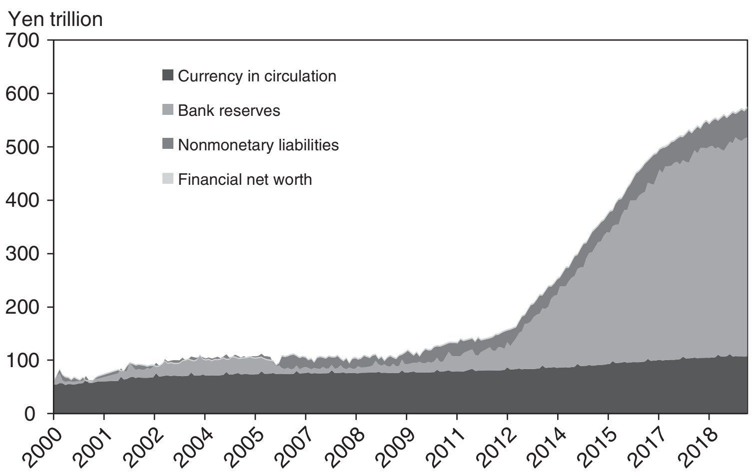

FIGURE 1.6B Japan BoJ liabilities

stock of bank reserves can also be viewed as irredeemable – at most the holder can insist on redemption in the form of currency, and even that is not self-evident.

So

$$M = J + Z$$

$$Z = Z^r + Z^e$$

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1.2.a Two Measures of Seigniorage and the Present Value Seigniorage Identity

Two useful measures of "flow seigniorage," the current revenue obtained by the central bank from its issuance of base money, are:[5]

$$\begin{aligned}\Omega_t^1 \equiv\ & M_{t+1} - (1 + i_{t,t-1}^M)M_t \\ =\ & \Delta M_{t+1} \quad \text{if } i_{t,t-1}^M = 0\end{aligned} \tag{1.1}$$

and

$$\begin{aligned}\Omega_t^2 \equiv\ & (i_{t,t-1} - i_{t,t-1}^M)M_t \\ =\ & i_{t,t-1}M_t \quad \text{if } i_{t,t-1}^M = 0\end{aligned} \tag{1.2}$$

where $i_{t,t-1}^M$ is the average interest rate on the monetary base:

$$i_{t,t-1}^M = i_{t,t-1}^J \left(\frac{J_t}{M_t}\right) + i_{t,t-1}^r \left(\frac{Z_t^r}{M_t}\right) + i_{t,t-1}^e \left(\frac{Z_t^e}{M_t}\right)$$

The first measure, Ω^1, represents the command over real resources achieved in period t by the issuance of base money in that period. When the nominal interest rate on base money is zero (as it is for its currency component), Ω^1 is just the change in the monetary base. The second measure represents the interest saved in a period by having borrowed through the issuance of base money liabilities rather than through the issuance of nonmonetary debt or, equivalently, the profit earned in a given period by holding monetary liabilities and an equal amount of nonmonetary assets.

A few more bits of notation are required: I_{t_1,t_0} is the nominal stochastic discount factor between periods t_1 and t_0.[6] It is related as follows to the risk-free, one-period nominal interest rate: $\frac{1}{1+i_{t+1,t}} = E_t I_{t+1,t}$; R_{t_1,t_0} is the real stochastic discount factor between periods t_0 and t_1; it is related to the risk-free, one-period real interest rate as follows: $\frac{1}{1+r_{t+1,t}} = E_t R_{t+1,t}$; $\Pi_{t_1,t_0} = \frac{P_{t_1}}{P_{t_0}}$ is the inflation factor between periods t_0 and t_1. The three factors are related by:

5 $\Delta X_t \equiv X_t - X_{t-1}$. The time subscripts of asset stocks refer to the beginning of the period in which they are held.

6 The mathematics of stochastic discount factors can be found in the Appendix to Chapter 1.

$R_{t_1,t_0} = I_{t_1,t_0}\Pi_{t_1,t_0}$. The real growth–corrected stochastic discount factor between periods t_0 and t_1, $\overline{R}_{t_1,t_0}$ is defined analogously. Let Y_t be real GDP in period t. The real growth factor between periods t_0 and t_1 is defined by $\Gamma_{t_1,t_0} = \frac{Y_{t_1}}{Y_{t_0}}$. The real growth–corrected stochastic discount factor is defined by $\overline{R}_{t_1,t_0} = R_{t_1,t_0}\Gamma_{t_1,t_0}$.

We also define the following notation: For any sequence of nominal payments $X_j,\ j = 1, 2, \ldots.$, the present discounted value (PDV) at the beginning of period t of all current and future values of $X_j,\ P_j$ is defined as $V_t(\{X, I\}) \equiv E_t\sum_{j=t}^{\infty} I_{j,t}X_j$. For any sequence of real payments $X_j/P_j, j = 1, 2, \ldots.$, the PDV at the beginning of period t of all current and future values of X_j/P_j is defined as $V_t\left(\left\{\frac{X}{P}, R\right\}\right) \equiv E_t\sum_{j=t}^{\infty} R_{j,t}\frac{X_j}{P_j}$. For any sequence of payments as a share of GDP, $X_j/(P_jY_j), j = 1, 2, \ldots.$, the PDV at the beginning of period t of all current and future values of x_j using growth-adjusted real discount rates is defined as $V_t\left(\left\{\frac{X}{PY}, \overline{R}\right\}\right) \equiv E_t\sum_{j=t}^{\infty}\overline{R}_{j,t}\frac{X_j}{P_jY_j}$

It can be shown by brute force that the two seigniorage measures are related as follows by the intertemporal seigniorage identity (see also Buiter (2007a)):

$$E_t\sum_{j=t}^{\infty}{}_{j,t}\left(M_{j+1} - (1 + i^M_{j,j-1})M_j\right) \equiv E_t\sum_{j=t}^{\infty} I_{j+1,t}(i_{j+1,j} - i^M_{j+1,j})M_{j+1} \\ -(1 + i^M_{t,t-1})M_t + \lim_{j\to\infty} E_tI_{j,t}M_{j+1} \qquad (1.3)^{7}$$

In words, the PDV of current and future changes in the monetary base (corrected for any interest paid on the monetary base) equals the PDV of current and future profits earned from investing the current and future money stocks, minus the initial value of the stock of base

[7] In continuous time, without uncertainty, the intertemporal seigniorage identity is:

$$\lim_{v\to\infty}\left(\int_t^v e^{-\int_t^s i(u)du}\left(\dot{M}(s) - i^M(s)M(s)\right)ds\right) \\ = \lim_{v\to\infty}\left[\int_t^v e^{-\int_t^s i(u)du}\left(\left(i(s) - i^M(s)\right)M(s)\right)ds + e^{-\int_t^v i(u)du}M(v)\right] - M(t)$$

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money plus the PDV of the terminal stock of base money. We can write (1.3) more compactly as:

$$V_t(\{\Omega^1, I\}) = V_t(\{\Omega^2, I\}) + V_t(\lim_{j\to\infty} M_{j+1}, I)$$
$$-(1 + i^M_{t,t-1})M_t \tag{1.4}$$

If we want to study the behavior of an economy that is permanently stuck at the effective lower bound, as we do in Chapter 5, it is not sensible to assume that the PDV of the terminal base money stock, $\lim_{j\to\infty} E_t I_{j,t} M_{j+1} = V_t(\lim_{j\to\infty} M_{j+1}, I)$ equals zero in the long run. This may well be the case for Japan, as is clear from Figure 1.7, which shows the uncollateralized overnight call rate since 1998.

Except in such a permanent liquidity-trap equilibrium, the assumption that the stock of nominal base money does not forever grow at a rate equal to or greater than the short nominal interest rate is probably unobjectionable.

Our two flow seigniorage measures as a share of GDP, $\omega^1_t = \frac{\Omega^1_t}{P_t Y_t}$, and $\omega^2_t = \frac{\Omega^2_t}{P_t Y_t}$ are given by:

$$\omega^1_t = \frac{\Delta M_{t+1} - i^M_{t,t-1} M_t}{P_t Y_t} = (1 + \pi_{t+1,t})(1 + \gamma_{t+1,t}) m_{t+1}$$
$$-(1 + i^M_{t,t+1}) m_t$$
$$\omega^2_t = \frac{(i_{t,t+1} - i^M_{t,t+1}) M_t}{P_t Y_t} = (i_{t,t+1} - i^M_{t,t+1}) m_t \tag{1.5}$$

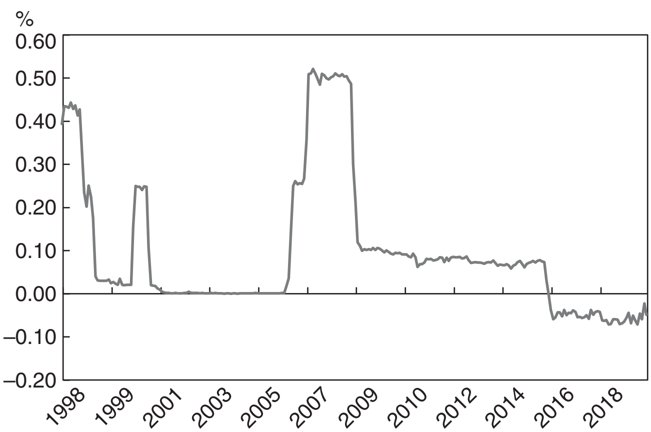

FIGURE 1.7 Yen uncollateralized overnight call rate

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where $m_t = \frac{M_t}{P_t Y_t}$ is the monetary base as a share of GDP (the reciprocal of the income velocity of circulation of base money), $1 + \pi_{t+1,t} = P_{t+1}/P_t$ and $1 + \gamma_{t+1,t} = Y_{t+1}/Y_t$.

1.2.b How Much Seigniorage Can Be Extracted?

What would the values of these two seigniorage measures be for the USA if the economy were at its inflation target, assumed to be 2.0 percent, and real GDP growth were, say, 2.0 percent – a reasonable number for the growth rate of potential output of the USA? We will assume that the interest rate on required and excess reserves is zero (i.e. we set $i^M = 0$ in equation (1.5)), which flatters the magnitude of the seigniorage calculations.

As of March 13, 2019, the total monetary base was \$3,430 bn, split almost equally between currency in circulation (\$1,717 bn) and total balances maintained (\$1,713 bn).[8] The US nominal GDP in 2018 was \$20,513 bn. The monetary base is therefore 16.72 percent of annual GDP. The "noninflationary" seigniorage that can be extracted according to the ω^1 measure (assuming that $m_{t+1} = m_t$) is therefore 0.68 percent of GDP. If we narrow down the seigniorage concept to just the change in the stock of currency in circulation, the noninflationary seigniorage as a share of GDP would be 0.34 percent of GDP. This number no doubt comes as a disappointment to some proponents of Modern Monetary Theory (MMT), who at times appear to confuse the large amount of monetary deficit financing that is feasible and safe at the ELB, when the economy is in a liquidity trap, with the noninflationary monetary deficit financing that is possible away from the ELB (see, e.g., Bell (2000), Tcherneva (2002), Forstater and Mosler (2005), Wray and Forstater (2005), Mosler (2010), Wray (2015, 2018) and Roche (2019)). Fullwiler et al. (2019) do not make this mistake.

Note that at the ELB, when the economy is in a liquidity trap, the stock of money balances as a share of GDP can be increased through nominal base money issuance; that is, m_{t+1} can be made

[8] See Federal Reserve Board; www.federalreserve.gov/releases/h3/current/.

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larger than m_t in equation (1.5) by possibly highly significant amounts, because the demand for real money balances at the ELB is infinitely interest-elastic. This accounts for the extraordinarily large seigniorage numbers in some of the years following the GFC, shown in Table 2.11 in Chapter 2.

The ω^2 measure of seigniorage (interest saved) would be the same as the ω^1 measure if the nominal interest rate were 4 percent. Current estimates of the short-term neutral nominal interest rate in the USA tend to be 3 percent or less, however. With $i = 0.03$, and again assuming $i^M = 0$, the interest saved would be 0.5 percent of GDP if we include the entire monetary base in the calculation. It would be 0.25 percent of GDP if we included just currency in circulation.

Instead of asking how much seigniorage can be extracted with inflation at its target value, we might be interested in the maximum amount of seigniorage as a share of GDP that can be extracted at any *constant* rate of inflation. This rules out hyperinflation equilibria. To answer this question, we need to know how the demand for real money balances varies with the rate of inflation. That means we have to have an estimate of a base money demand function. We restrict the analysis in what follows to the demand for currency in circulation, in part because the current US interest rate on required and excess reserves is very close to the market interest rate (it was 2.40 percent on March 16, 2019, and 1.80 percent on September 23, 2019), so very little seigniorage is currently earned on this component of the monetary base.

A standard Cagan-style demand function for currency takes the form:[9]

$$\begin{aligned}&\frac{J}{P} = kY^{\alpha}e^{-\beta(i-i^J)}\\&k,\alpha,\beta > 0\end{aligned} \tag{1.6}$$

[9] The Cagan (1956) base money demand function does not have the property, used elsewhere in this book, that the demand for real base money becomes infinitely interest-sensitive when the nominal interest rate is zero. From equation (1.6), when $i = i^J = 0$, $\frac{J}{P} = kY^{\alpha}$.

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With the interest rate on currency, i^J, equal to zero, it follows that, at a constant nominal interest rate, the growth rate of the stock of currency, μ, the rate of inflation, π, and the growth rate of real GDP, γ, are related as follows:

$$1 + \mu = (1 + \pi)(1 + \gamma)^{\alpha} \tag{1.7}$$

The steady-state values of the two seigniorage measures as shares of GDP – if a steady state exists – are given by:

$$\begin{aligned} \omega^1 &= \Big((1 + \pi)(1 + \gamma) - (1 + i^M)\Big)m \\ \omega^2 &= (i - i^M)m \end{aligned} \tag{1.8}$$

In the case of revenue from currency alone, this becomes, using (1.6) and $i^M = i^J = 0$:

$$\begin{aligned} \omega^1 &= \Big((1 + \pi)(1 + \gamma) - 1\Big)kY^{\alpha-1}e^{-\beta i} \\ \omega^2 &= ikY^{\alpha-1}e^{-\beta i} \end{aligned} \tag{1.9}$$

Of course, we can only have a steady state if either α, the output elasticity of currency demand, equals 1 or if the growth rate of real GDP is zero.

The Global Economics team at Citi have produced estimates of long-run currency demand functions for the euro, the US dollar, the pound sterling and the Japanese yen, based on equation (1.6), allowing for nonstationarity, common trends and structural breaks in the relevant series (see, e.g., Buiter (2013)).

The estimation yields a robust estimate for the output elasticity of currency demand, α, for the euro, the US dollar and sterling of around 0.8 (and around 1.0 for the yen), implying that every 1 percent increase in real output calls forth a 0.8 percent (1.0 percent for the yen) increase in real money balances demanded. The interest rate semi-elasticity of currency demand is somewhat less precisely estimated. The average coefficient value estimated for β is around 3 for the euro area (but considerably higher for the United States at 7.2), implying that a 1 percentage point increase in a short-term nominal market interest rate (our opportunity cost measure) implies a 3 percent decrease in the demand for real euro currency balances.

To continue the steady-state analysis, we set $\alpha = 1$, which will mean an overestimate of long-run seigniorage for the euro, the US dollar and sterling at any constant rate of inflation. We assume that the one-period, risk-free nominal interest rate and the one-period, risk-free real interest rate are related through the Fisher equation:

$$1 + i = (1 + r)(1 + \pi) \tag{1.10}$$

This gives us:

$$\begin{aligned} \omega^1 &= \Big((1+\gamma)(1+\pi) - 1\Big)ke^{-\beta((1+r)(1+\pi)-1)} \\ \omega^2 &= \Big((1+r)(1+\pi) - 1\Big)ke^{-\beta((1+r)(1+\pi)-1)} \end{aligned} \tag{1.11}$$

Taking the real interest rate and the growth rate of real GDP as given, the inflation rate that maximizes ω^1 is given by:

$$\hat{\pi}_{\omega^1} = \frac{1}{(1+r)\beta} - \frac{\gamma}{1+\gamma} \tag{1.12}$$

and the inflation rate that maximizes ω^2 is given by:

$$\hat{\pi}_{\omega^2} = \frac{1}{(1+r)\beta} - \frac{r}{1+r} \tag{1.13}$$

The maximum steady-state values of our two flow seigniorage measures are:

$$\hat{\omega}^1 = \frac{(1+\gamma)}{(1+r)\beta}ke^{-\left(1+\beta\left(\frac{r-\gamma}{1+\gamma}\right)\right)} \tag{1.14}$$

and

$$\hat{\omega}^2 = \left(\frac{1}{\beta}\right)ke^{-1} \tag{1.15}$$

The two seigniorage maximizing inflation rates and the maximized value of seigniorage as a share of GDP are the same if the real interest rate equals the growth rate of real GDP – if the economy is at the Golden Rule.

For the USA, our point estimate of β is 7.2 (a rather high number). Assume for illustrative purposes that the real growth rate and the real interest rate are both 2 percent. We estimate k by taking the ratio

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Table 1.1 *Steady-state inflation rate that maximizes seigniorage as a share of GDP*

Country/ currency	Year	β	k=Ratio of currency to annual GDP	$r = \gamma$ (%)	$\hat{\pi}^1$ (%)	$\hat{\omega}^1$ (%)
Eurozone	2013	2.9	0.096	1.0	33.2	1.22
US	2014	7.2	0.073	2.0	11.7	0.37
Japan	2015	2.0	0.185	0.5	49.3	3.40
UK	2016	1.7	0.039	1.5	56.5	0.84

Source: own calculations

of currency in circulation to GDP in the most recent year when the interest rate on excess reserves was (near) zero. For Japan this is 2016, for the United States 2014, for the Eurozone 2013 and for the United Kingdom 2016.

Given these assumptions (including the counterfactual one for the United States, the United Kingdom and the Eurozone that the output elasticity of currency demand equals 1), the constant rate of inflation that maximizes the share of seigniorage in GDP in the USA is a low 11.66 percent. The maximum share of seigniorage in GDP in the USA is a low 0.37 percent. Both these low numbers reflect the high value of β. If we assume instead that the interest semi-elasticity of US dollar currency demand is 2.0, the constant inflation rate that maximizes steady-state seigniorage as a share of GDP for the USA is 47.1 percent and the maximum constant share of seigniorage in GDP is 1.34 percent. Japan's maximum sustainable seigniorage is 3.4 percent of GDP at an inflation rate of 49.3 percent.

Although 1.34 percent of GDP on a recurrent basis is nothing to be sniffed at, it is a useful qualifier to the PDV calculations in the next subsection. When you are considering an infinite horizon, dramatic things can happen if the gap between the discount rate and the growth rate of what is discounted is small.

1.2.c The Present Value of Seigniorage Revenues

We are interested in the empirical magnitude of the present discounted value of current and future seigniorage at the beginning of period t, denoted $V_t(\{\Omega^1, I\})$, that is:

$$V_t(\{\Omega^1, I\}) = E_t \sum_{j=t}^{\infty} I_{j,t-1}\left(M_{j+1} - (1 + i^M_{j,j-1})M_j\right) \tag{1.16}$$

The reason for our interest is that $V_t(\{\Omega^1, I\})$, the PDV of current and future seigniorage, is a key asset in the comprehensive balance sheet (or intertemporal budget constraint) of the central bank and the State – an asset that is absent from the conventional balance sheet but that is essential in assessing the solvency of the central bank and the State. These ideas are developed further in Chapter 2. Clearly, central bank solvency should never be a problem unless the central bank has significant foreign-currency-denominated or index-linked liabilities.[10] If this is not the case, the central bank should always be able to service its debt obligations by adding to the monetary base ("printing money"). The only (political) constraint on this is the inflation that will be generated, sooner or later, if the nominal stock of base money grows at a sufficiently high rate for a sufficiently long period of time. An interesting benchmark is the PDV of current and future seigniorage if the inflation rate is at its target level. If that PDV is a sufficiently large number, we can be reasonably confident that the central bank will be able to discharge all its financial obligations without having to engage in excessively inflationary monetary base expansion.

An empirical implementation of equation (1.16) is a heroic task, which we tackle by making the heroic simplification of stationarity. Specifically, we assume that the proportional growth rate of the monetary base is a constant μ and that the short nominal interest rate is a constant i. We also restrict the consideration of the monetary base to the currency component, omitting required and excess reserves

10 Strictly speaking, only "deliverable" index-linked securities – bonds promising to pay a given amount of physical real output each period – create unavoidable default risk.

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issuance as a source of seigniorage. This means that we set $M = J$ and $i_j^J = 0$ in equation (1.16). We therefore err on the side of underestimating the size of the NPV of future seigniorage.

The PDV of current and future currency issuance can now be written as

$$V(\{\Omega^1, I\}) = \left(\frac{1+i}{1+i-(1+\pi)(1+\gamma)^{\alpha}}\right)\Big((1+\pi)(1+\gamma)^{\alpha}-1\Big)J_0 \qquad (1.17)$$

where J_0 is the initial value of the stock of currency.

To arrive at estimates of the present discounted value of seigniorage when inflation is at its target rate, we need to combine our estimated coefficients with assumptions about future real growth rates for the euro area and discount rates for the stream of seigniorage revenue. A reasonable estimate for the long-run real growth rate of the euro area would be around 1 percent pa. The long-run nominal discount rate presents something of a problem in this age of extraordinarily low nominal and real interest rates. It is very easy to get infinite values for the PDV of future seigniorage revenues (and for the PDV of future central bank operating costs, discussed in Chapter 2) even with interest rates in excess (for the Eurozone, Japan and the United Kingdom *well* in excess) of their current values.

We now use this PDV of current and future seigniorage framework to make estimates of the noninflationary loss absorption capacity (NILAC) of a number of central banks. This analysis draws on writings by Buiter (2010, 2013) and Buiter and Rahbari (2012a, b). "Noninflationary" here again means an inflation rate of 2 percent for the GDP deflator – a reasonable approximation to the inflation targets of the monetary authorities we are considering. Table 1.2 presents the estimates for the value of the PDV of Eurosystem seigniorage based on our benchmark assumptions about the output elasticity of currency demand, α, the semi-elasticity of currency demand with respect to the short nominal interest rate, β, the rate of inflation, π, as well as a number of alternative assumptions for real GDP growth rates, γ, and nominal interest rates, i. As Table 1.2 indicates, the resulting value

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Table 1.2 *Present discounted value of future seigniorage in the euro area (α=0.8; β=2.9; π=0.02)*

EUR (bn)	Interest/Discount Rate (i)				
Real Growth Rate (γ)	2.5%	3.0%	3.5%	4.0%	4.5%
0.5%	30,428	4,692	2,520	1,712	1,290
1.0%	infinite	17,579	4,698	2,690	1,873
1.5%	infinite	infinite	13,256	4,689	2,827
2.0%	infinite	infinite	infinite	11,064	4,669

Note: α represents the long-run income elasticity of the money demand function, and β the corresponding interest rate semi-elasticity.
Source: Citi Investment Research and Analysis

would be just under €2.7 tn at a 1 percent average real growth rate and with a nominal discount rate of 4 percent. Raising the average growth rate of real GDP to 1.5 percent raises the estimate of the present discounted value of seigniorage by 74 percent. Note that the relevant growth rate here is the average growth rate in the future, with the horizon being infinite. Even with a real GDP growth rate as low as 0.5 percent, a nominal discount rate of 2.5 percent would generate a PDV of seigniorage of just over €30 tn. A 2 percent nominal discount rate would result in an infinite PDV of seigniorage, even with real GDP growth at 0.5 percent – the long-run growth rate of the nominal stock of currency exceeds the nominal discount rate in this case.

The corresponding estimates and calculations for US dollar, sterling and yen currency demand and seigniorage are given in Tables 1.3, 1.4 and 1.5, respectively.

By any standards, these estimates of the PDV of noninflationary seigniorage are large numbers. For the euro area, as noted, at 2 percent inflation, 1 percent real GDP growth and a 4 percent nominal interest rate, it comes to €2.7 tn (see Table 1.2). For the USA, with 2 percent inflation, real GDP growth at 2 percent and a 4 percent nominal discount rate, the PDV of future noninflationary seigniorage is \$13.7 tn (see Table 1.3). For the United Kingdom, with 2 percent inflation,

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Table 1.3 *Present discounted value of future seigniorage in the United States (α=0.8; β=7.2; π=0.02)*

US$ (bn)	Interest/Discount Rate (i)				
Real Growth Rate (γ)	2.5%	3.0%	3.5%	4.0%	4.5%
0.5%	40,093	6,051	3,180	2,115	1,560
1.0%	infinite	22,670	5,930	3,322	2,265
1.5%	infinite	infinite	16,731	5,793	3,418
2.0%	infinite	infinite	infinite	13,668	5,645
2.5%	infinite	infinite	infinite	infinite	11,760

Note: α represents the long run income elasticity of the money demand function, and β the corresponding interest rate semi-elasticity.
Source: Citi Investment Research and Analysis

Table 1.4 *Present discounted value of future seigniorage in the United Kingdom (α=0.8; β=1.7; π=0.02)*

UK£ (bn)	Interest/Discount Rate (i)				
Real Growth Rate (γ)	2.5%	3.0%	3.5%	4.0%	4.5%
0.5%	1,956	303	164	112	85
1.0%	infinite	1,137	306	176	123
1.5%	infinite	infinite	862	307	186
2.0%	T	infinite	infinite	724	307
2.5%	infinite	infinite	infinite	infinite	640

Note: α represents the long run income elasticity of the money demand function, and β the corresponding interest rate semi-elasticity.
Source: Citi Investment Research and Analysis

1.5 percent real growth and a 4 percent discount rate, the PDV is £307bn. With 2 percent real growth this becomes £724 bn (see Table 1.4). For Japan, with a 0.5 percent trend real GDP growth and a 4 percent discount rate, the PDV is ¥172 tn (see Table 1.5). If we used discount rates closer to what has been the norm since the start of QE

Table 1.5 *Present discounted value of future seigniorage in Japan (α=1.0; β=2.0; π=2.0)*

Yen (tn)	Interest/Discount Rate (i)				
Real Growth Rate (γ)	2.5%	3.0%	3.5%	4.0%	4.5%
0.5%	infinite	529	261	172	128
1.0%	infinite	infinite	647	315	208
1.5%	infinite	infinite	infinite	768	370
2.0%	infinite	infinite	infinite	infinite	893

Note: α represents the long run income elasticity of the money demand function, and β the corresponding interest rate semi-elasticity
Source: Citi Investment Research and Analysis

(say, 2 percent) the PDV of future seigniorage would be robustly infinite.

The numbers in Tables 1.2 to 1.5 underestimate the noninflationary loss-absorbing capacity or NILAC of the central bank for a number of reasons. First, it excludes required and excess reserves from the exercise, or assumes they are paid the market opportunity cost and therefore don't represent a source of profit to the central bank. Even if this were correct currently, it is at the discretion of the central bank, which sets both the reserve requirement and the rates of remuneration on required reserves and excess reserves. The required reserve ratio for the euro area was lowered (on December 8, 2011) to 1 percent of eligible deposits from 2 percent. The United Kingdom has no required reserves other than those required to be held under the *de minimis* Cash Ratio Deposit Scheme. As regards excess reserves, the availability of private and other sovereign substitutes limits the ability of the central bank to extract rents from these liabilities. The new liquidity requirements of Basel 3 (the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR)) have, however, made holding excess reserves with the central bank more attractive to banks, and the central bank could extract greater rents from "excess reserves" because of that.

Second, it ignores the conventional loss-absorption capacity of central banks. In the case of the Eurosystem, this amounted, as of December 31, 2017, to €102.7 bn of Capital and reserves, plus €357.9 bn worth of revaluation accounts – mostly revaluation gains on gold and foreign exchange reserves. For the Bank of England on February 28, 2018, capital plus reserves was £4.5 bn. There is not enough detail in the published accounts to uncover the existence and valuation of the Bank of England's revaluation gains.[11]

Finally, from the intertemporal seigniorage identity (equations (1.3) or (1.4)) (see also Chapter 2 and Buiter (2007a)), the intangible asset that has to be added to the conventional balance sheet of the central bank (which already contains the outstanding stock of base money as a liability, of course) to obtain its noninflationary loss absorption capacity is not just the PDV of future currency issuance but the sum of the PDV of future currency issuance and the initial stock of currency, about €1,171 bn for the euro area stock of banknotes at the end of December 2017.[12] This means that the noninflationary loss-absorption capacity of the Eurosystem with $\gamma = 1\%$, $\pi = 2\%$ and $i = 4\%$ is €4.3 tn. For the Bank of England, with $\gamma = 1.5\%$, $\pi = 2\%$ and $i = 4\%$, the total contribution to the NILAC from seigniorage is £386 bn, of which about £74 bn comes from the outstanding stock of currency (as of March 31, 2017) and about £4.8 bn from capital and reserves.[13]

We must of course, subtract the PDV of the operating costs – the cost of running the monetary authority – to get a correct measure of the PDV of the fiscal space potentially created by the central bank. For these purposes, we should estimate the cost of running the central

11 Bank of England Annual Report and Accounts, 1 March 2017–28 February 2018. The Bank of England publishes data for the consolidated balance sheet (banking and issue departments) only with a five-quarter lag. Most other leading central banks provide this information at monthly or even weekly frequencies with minimal lags.

12 I assume for the purpose of these calculations that the NPV of the terminal stock of base money is zero.

13 Bank of England, Annual Report 2014, page 54, www.bankofengland.co.uk/publications/Documents/annualreport/2014/boereport.pdf. I could not make heads or tails of the treatment of the £41 bn off-balance sheet Funding for Lending Scheme item, including whether this was an asset, a liability or both, so it has been ignored in the calculation.

bank acting as a narrow monetary authority, stripping out the cost of its supervisory and regulatory functions. There is no fully satisfactory way to do this, however, because the ECB (since 2014), many of the Eurosystem national central banks, the Fed, the Bank of England (since 2015) and the Bank of Japan all combine the role of monetary authority with material supervisory responsibilities. Estimates of the cost of running the monetary authority based on the cost of running these central banks will be biased upwards (other things being equal).

The total annual operating cost of the Eurosystem were €9,7 bn in 2017. If we assume constant real operating costs, 2 percent inflation and a 4 percent nominal discount rate, we obtain a PDV of current and future operating costs of €504.4 bn. If instead we assume that the real operating costs rise at the same rate as real GDP, 1 percent, say, the PDV of operating costs is €1,029.4 bn. Note that this does include costs associated with the supervisory and regulatory activities of the ECB and the nineteen NCBs. The Eurosystem's "net" NILAC, that is NILAC minus the PDV of operating costs, is around €3 tn.

The total operating costs of the Banking Department and the Issue Department of the Bank of England in 2017 was £518 mn. This excludes the operating costs of the Prudential Regulatory Authority (PRA), which accounts for most of the supervisory and regulatory activities now undertaken by the Bank of England. If we assume constant real operating costs, 2 percent inflation and a 4 percent nominal discount rate, this results in a PDV of current and future operating costs of £26.9 bn. If instead we assume that the real costs rise at the same rate as real GDP, 1.5 percent, say, the PDV of operating costs is £114.6 bn. In the latter case, the net NILAC of the Bank of England is therefore around £271 bn.

These numbers are large enough to get excited about. These resources are, of course, tax payers' resources and should be accounted for properly. In Chapter 2, we consider in greater detail the implications of the consolidation of the accounts of the Treasury and central bank that is a logical implication of the Treasury's beneficial ownership of the central bank.