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The central bank balance sheet as a policy tool: past, present and future

Paper prepared for the Jackson Hole Economic Policy Symposium, 27–28 August 2020

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1 Many colleagues have contributed to the ideas and analysis in this paper. We would like to thank, without implicating, Saba Alam, Ben Broadbent, Andrew Hauser, James Howat, Raf Kinston, Nick McLaren and Tim Taylor for discussions that materially influenced the arguments in the paper. We are grateful to Charlotte Barton, Julia Giese, Jonathan Hall, Bonnie Howard, Mike Joyce, Don Kohn, Clare Macallan, Sean Maloney, James Proudman, Dave Ramsden, Kate Reinold, Elisabeth Stheeman and Ryland Thomas for helpful comments and discussions. Liam Jordison, Asja Karanusic, Alister Ratcliffe and Millie Rettie provided excellent research assistance.

Introduction

The start of a new decade always prompts contemplation about the future. The Federal Reserve Bank of Kansas City's 2020 Economic Policy Symposium provides an opportunity to do just that, with a focus on monetary policy. This continues a Jackson Hole tradition.[2]

There are some similarities with the macroeconomic situation a decade ago. Short-term policy rates are at their floors in many jurisdictions. Central bank balance sheets have reached historically unprecedented levels, as a result of prompt and substantial policy responses to an enormous global shock. One important difference, though, is that the nature of the shock to the world economy is fundamentally different. Another is that some policy measures that were unprecedented at the time of the Global Financial Crisis (GFC) of 2007-2009 are now more familiar parts of the central bank toolkit.

Against that backdrop, this paper focuses on what has been learned from the past decade of previously unconventional policy measures and the emerging lessons from the effects of policy responses to the Covid shock. In light of that, the paper also presents some speculative views on the implications for future central bank balance sheet policies and the operational framework to support them. The intention is to highlight some important questions for researchers and policymakers for the decade ahead.

Section 1 reviews central bank balance sheet developments, primarily from a UK perspective, from the GFC to the end of 2019. The largest contributor to balance sheet expansion on the liabilities side of the Bank of England balance sheet over this period was reserves. On the asset side of the balance sheet, the largest contributor was driven by purchases of long-term government bonds, "quantitative easing" (QE) by the Bank's Monetary Policy Committee (MPC). While scale does not always signify importance, the paper focuses on these components.

With the benefit of hindsight, the quantity of high quality liquid assets (HQLA) held by the banking system before the GFC was insufficient. The surge in commercial banks' demand for liquidity during the GFC highlighted a structural shift in demand, as well as the need for a decisive use of the central bank balance sheet to restore financial stability. The QE programmes following the GFC resulted in a large increase in the quantity of reserves, so that liquidity within the banking system became abundant. The reserves created as a by-product of QE operations therefore coincided with a large increase in the demand for reserves for liquidity management by the commercial banking system.

The widespread adoption of large-scale asset purchase programmes around the world spawned a rich body of empirical and theoretical work on the impact of QE, which has grown rapidly over the past decade.

There is broad consensus that QE programmes have been successful in lowering government bond yields, often by a considerable amount. Estimates of the macroeconomic effects are less certain, as each step along the QE transmission mechanism – with the associated lags at each stage – makes it harder to credibly identify causal effects. On balance, though, the literature provides evidence of ongoing QE transmission to the macroeconomy and supports the view that at least some of the associated transmission channels are persistent.

An accompanying theoretical literature has explored those transmission channels, and the paper considers three broad groups, associated with: policy "signalling"; the "portfolio balance channel"; and market liquidity. The review of this literature in Section 1, while noting the inherent difficulties in

2 The 2010 symposium focused on "Macroeconomic Challenges: The Decade Ahead" and Bank of England Deputy Governor Charlie Bean spoke at a session on "Rethinking Monetary Policy in Light of the Crisis".

distinguishing between alternative transmission channels, concludes that there is evidence of each channel. Importantly, these channels need not be mutually exclusive.

Section 2 considers the policy response to the Covid crisis, where again the central bank balance sheet played a crucial role. In the UK, the Bank of England balance sheet is now larger than at any point in its history.

The recent policy actions taken by the Bank of England were large, rapid and wide-ranging. The range of actions spanned monetary policy decisions to deliver financial conditions consistent with achieving the inflation target, liquidity operations to stabilise money markets and funding schemes to support corporate financing. Other central banks responded in a similar way. Post-GFC tools were re-deployed in extended or recalibrated forms and new interventions were introduced, incorporating innovations to target them to the specific properties of the Covid shock.

It is too soon to draw firm conclusions on the efficacy of the policy response to Covid and the role of the central bank balance sheet within that. However, some initial – necessarily tentative – observations may provide some helpful guides for future debate. These observations focus on QE, which again played a central role in the crisis response.

First, decisive QE programmes may be particularly effective in times of market dysfunction. Second, a rapid pace of asset purchases may also enhance QE effectiveness during these periods. Taken together, these observations suggest a particular form of 'state contingency' for the impact of QE. Recognition of this potential for state contingency is not new, but the recent crisis offers a new lens through which to assess its role.

The MPC decides on the overall stock of QE to deliver the required stimulus to meet the inflation target, given prevailing financial conditions. Consistent with the two observations above, the decision to 'go big' and to 'go fast' with QE in March 2020, a period of market dysfunction, may well have also avoided an undesirable tightening in those financial conditions. Left unchecked, the market dysfunction at that time could otherwise have amplified the substantial weakening in the outlook for growth and inflation. Decisive action that was responsive to the degree of market dysfunction was a unifying theme across the global central bank responses to the Covid crisis.

A third observation is that QE efficacy may also depend on the origin of liquidity demand. The nature of the liquidity stresses in the Covid crisis differed from those experienced during the GFC, during which commercial banks were at the centre of the shock. In the Covid crisis, the MPC's asset purchases provided liquidity to gilt market investors so that outright QE purchases reached the non-bank investors experiencing the effects of liquidity stress and driving the associated market dysfunction.

Section 3 considers potential implications associated with these observations for the evolution of central bank balance sheets in the years ahead. Here the suggestions are necessarily more speculative and the objective is to raise questions for future research and policy debate.

Lessons from the past suggest that, for both financial stability and monetary policy purposes, the central bank balance sheet should move in a countercyclical manner. However, the persistence of the effects on the balance sheet from policy actions directed at these purposes may be somewhat different.

The most speculative line of enquiry considers the potential effects of state-contingent QE on monetary policy. The particular form of QE state contingency explored in Section 2 may provide a greater motivation for relying more on balance sheet unwind than increases in the policy rate to normalise the stance of policy when – and only when – such a normalisation becomes appropriate. If the effects of QE are more powerful in 'crisis' states of the world, a greater reliance on balance sheet unwind during normalisation could provide more scope to 'go big' and 'go fast' in response to future crisis shocks.

It would be unwise to extrapolate these conjectures too far. Any decision on future balance sheet policies would, as always, require judgement based on a careful assessment of economic theory, empirical evidence and practical considerations. However, the tentative and speculative analysis in Section 3 suggests that the question of the appropriate policy mix during a normalisation process may be more nuanced than had been previously thought.

A more concrete conclusion is that it is highly desirable for the operational framework to support a wide range of policy measures. In particular, the ideal size and composition of the balance sheet should be designed to support countercyclical balance sheet adjustments for both monetary policy and financial stability reasons.

A proposed balance sheet framework is set out in Section 3, which builds on recent Bank analysis and consultation. The proposal represents a natural middle ground between scarcity and overabundance of reserves. In steady-state, this framework supplies the level of reserves that banks demand,[3] thereby delivering market rates close to the desired policy rate. This approach also has the benefit of supplying the minimum level of reserves required for financial stability purposes independently of any decisions to adjust the stock of assets held for monetary policy purposes. Simple scenario analysis explores how the countercyclical balance sheet responds to alternative shocks that require policy responses targeted at monetary policy and financial stability.

A common lesson from both the GFC and the Covid crisis is that policymakers must be prepared to react decisively to the unexpected. For central banks, readiness to use the balance sheet as a policy tool lies at the heart of that preparedness. Many questions remain to be answered in the quest to better understand the effects of balance sheet policies, their optimal deployment and the operating framework that can best support them. This paper seeks to tee up some of those questions. Answering them is surely a priority for the decade ahead, for researchers and policymakers alike.

1: Lessons from the past

The crucial role played by the central bank balance sheet in the financial system has long been understood.[4] In the decade following the GFC central bank balance sheets were centre stage. That period witnessed large and sustained balance sheet expansions as a by-product of a host of previously unconventional policy measures. This section reviews the key drivers of balance sheet expansion since the GFC and their economic effects, focusing on the United Kingdom.

The majority of the expansion in the Bank of England's balance sheet since the GFC has been associated with the widespread use of "quantitative easing" or "QE", financed by the creation of central bank reserves (**Charts 1** and **2**).[5] Each side of the balance sheet is considered in turn.

3 Where reserves are freely supplied at the policy rate against high quality liquid collateral.

4 See, for example, Shafik (2016). Ramsden (2018) concludes that "the Bank's balance sheet is a key part of the infrastructure for securing monetary and financial stability for the good of the people of the UK".

5 The Bank of England balance sheet has some particular idiosyncrasies. For example, the Bank's Issue Department and Banking Department have separate balance sheets. References to the Bank's balance sheet in this paper refer to the consolidated balance sheet of both departments. Asset purchases as part of the Bank's quantitative easing programmes discussed in this paper appear on the Bank's balance sheet as an asset in form of a loan to the Asset Purchase Facility (APF). This is an important institutional feature in the United Kingdom, since any losses made by the APF are indemnified by HM Treasury. However, unless there is risk of confusion, this paper abstracts from this accounting procedure. Unless otherwise stated, the balance sheet is presented 'as if' the assets purchased by the APF appear directly on the Bank's balance sheet.

Chart 1 Assets on Bank of England Balance Sheet

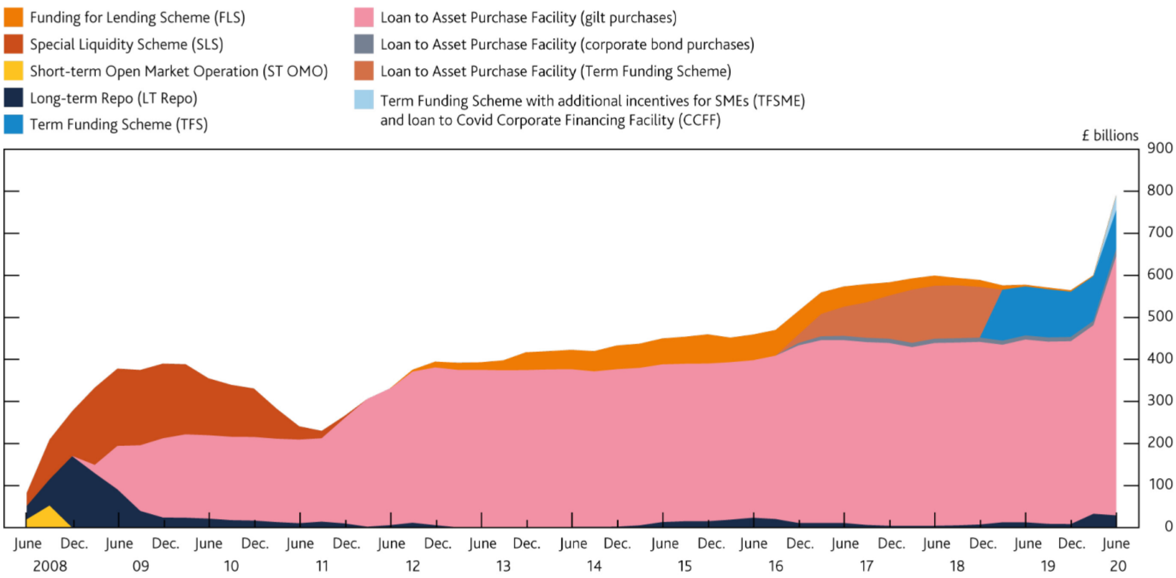
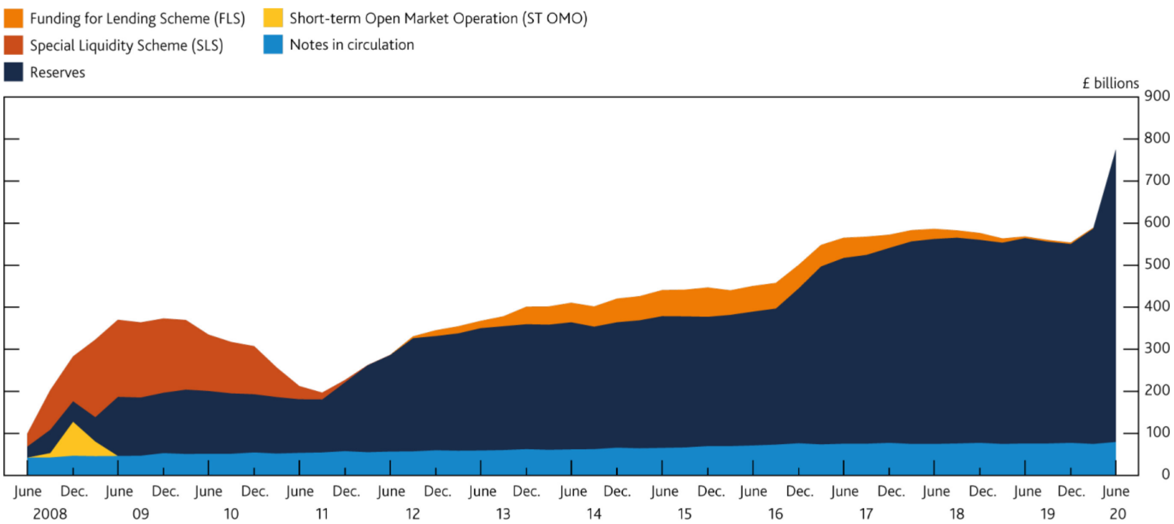


Chart 2 Liabilities on Bank of England Balance Sheet



Source: Bank of England. Charts are a stylised and partial view of the Bank's consolidated balance sheet and may not precisely balance as a result. The Bank's full consolidated balance sheet is published with a five quarter lag. Assets and liabilities from both the Bank's Issue Department and Banking Department have been consolidated into a single chart. See here for more detail. QE purchases are reflected on the Bank's balance sheet as an asset in form of a loan to the Asset Purchase Facility (APF). This chart shows a breakdown of the loan by instrument type. The Term Funding Scheme (TFS) was transferred from the APF to the Bank's own balance sheet in January 2019. The Special Liquidity and Funding for Lending Schemes (SLS and FLS respectively) were funded through asset swaps rather than reserves, so were not on balance sheet. They are nevertheless shown for context.

1.1 The effects of quantitative easing (QE)

Over the 2009-2019 period, the policy with the largest footprint on central bank balance sheets was QE.[6] In this paper, QE is defined as large-scale purchases of financial assets by a central bank, with the aim of providing monetary stimulus, by lowering long-term interest rates.[7]

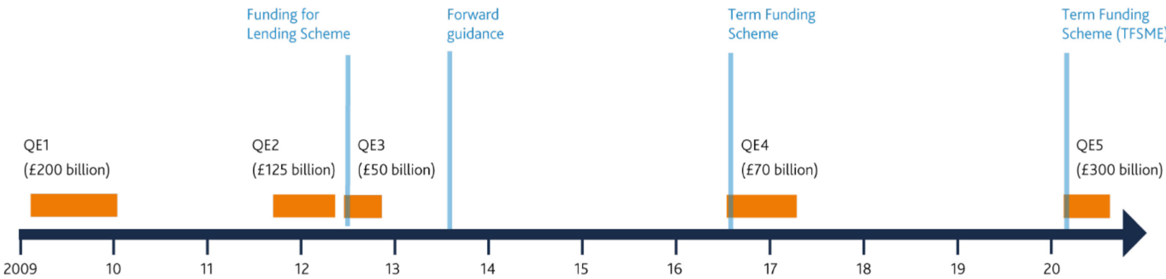
Over the past decade, QE has been widely used internationally, as policy rates have been cut to, or close to, their effective lower bounds. QE has therefore become the primary tool with which many central banks around the world have sought to affect monetary conditions.

6 Given this footprint, QE is the focus of this section. Section 3 returns to other interventions that affect the central bank balance sheet. These policies also have an important impact on the macroeconomy, by ensuring that economic conditions are not buffeted by instability in financial markets.

7 Note that the focus here is on the macroeconomic consequences of QE policy, rather than on the quantity of reserves created *per se*. Note also the broad definition of QE includes the purchase of both public and private sector assets (the latter is sometimes labelled separately as "credit easing").

In the United Kingdom, QE was first introduced in March 2009 in the depths of the GFC. The aim was to provide additional monetary stimulus when the policy rate became constrained at its effective lower bound.[8, 9] The Monetary Policy Committee (MPC) made QE purchases of £200bn during 2009-2010, with UK government bonds (gilts) making up the vast majority of assets purchased.[10] These gilts were purchased on the secondary market, predominantly from dealers acting on behalf of non-bank private sector institutions such as insurance companies and pension funds.[11] The MPC has subsequently engaged in multiple rounds of QE over the last decade in response to different economic shocks (**Figure 1**).[12] In August 2016, in response to the EU withdrawal referendum, the MPC extended its QE policy to purchase £10bn of investment-grade corporate bonds, alongside further gilt QE. Moreover, as discussed in Section 2, QE was a key element of the policy response to the Covid crisis, with the MPC announcing a further £300bn of asset purchases during March-June 2020, including further corporate bond purchases. When the current round of purchases is completed around the turn of the year, the total stock of UK QE will have risen to £745bn.

Figure 1 The Bank of England's QE journey



Internationally, asset purchases have played a similarly central role in monetary policy over the past decade. For example, the Fed embarked on large-scale purchases of agency MBS and debt issuance in November 2008 and of US Treasuries in March 2009. This was followed by the announcement of further purchases in late 2010, the Maturity Extension Programme in September 2011 and another round of open-ended purchases starting in late 2012. In Japan, asset purchases were first introduced much earlier, in 2001, and "Quantitative and Qualitative Easing" was a key part of the post-GFC response in 2013, while in Europe the ECB announced its "Public Sector Purchase Programme" in early 2015.[13] More recently, as discussed in Section 2, asset purchases have formed a key part of the central bank response to the Covid crisis around the world.

The UK's QE portfolio currently amounts to around 30% of nominal UK GDP and that share will continue to rise as the latest round of purchases are completed over the course of this year. For the Fed, ECB and Bank of Japan asset purchase schemes currently total around 27%, 28% and 104% of GDP respectively.[14]

8 When QE was introduced in the United Kingdom, the effective lower bound (ELB) was judged to be around 0.5%. A gradual change in the balance sheets of certain financial institutions and the introduction of the Term Funding Scheme led the MPC to conclude that the ELB was "close to, but above, zero" in the Minutes of the August 2016 MPC meeting.

9 For an excellent overview of different approaches taken internationally to asset purchases, see CGFS (2019).

10 Commercial Paper and Corporate Bonds also accounted for a small proportion of the MPC's asset purchases in 2009. These interventions were primarily designed to alleviate market dysfunction in those markets, which in turn aided the monetary policy transmission mechanism.

11 As noted in footnote 5, QE operations involve asset purchases by the Asset Purchase Facility, financed by a loan from the Bank. Another technicality is that all assets are purchased from dealers (part of the commercial banking system), the only firms that can participate in the Bank's asset purchase operations. Part of this activity will involve dealers intermediating on behalf of their non-bank clients who are the ultimate "sellers" of gilts. For simplicity, the dealer intermediation step in this process is omitted in the description in the text.

12 QE1 (2009/2010): £200bn, QE2 (2011/2): £125bn, QE3 (2012): £50bn, QE4 (2016): £70bn (including £10bn corporate bonds), and QE5 (2020): £300bn (including corporate bond purchases).

13 For a much fuller review of international asset purchase programmes see, for example CGFS (2019).

14 Based on latest available data as of early August. Fed data includes USTs, MBS and agency debt; ECB data covers all asset purchases for monetary policy (including corporate bonds); Bank of Japan data covers government securities. Nominal GDP figures are as at end-2019.

The large and sustained expansions of central bank balance sheets across the world over the past decade has prompted a burgeoning literature on the theoretical underpinnings of QE and the empirical evidence on its macroeconomic effects. A brief overview of each topic is given below.

The macroeconomic impact of QE in theory

Ahead of its adoption during the global financial crisis, many academics were sceptical that QE would have any effects on the macroeconomy at all. For example, the irrelevance proposition of Eggertsson and Woodford (2003) demonstrated that a change in the composition of households' portfolios induced by QE would have no effect on equilibrium asset prices or real variables in a widely studied benchmark model.[15] This result rested on some strong assumptions, including: i) perfectly functioning financial markets (the so called 'efficient market hypothesis'); ii) the absence of non-pecuniary advantages to different assets; and iii) investors' preferences characterised by a particular class of utility function. These assumptions are, however, typical of many mainstream macroeconomic models, particularly those developed before the global financial crisis.

In the decade of research that has followed, theoretical frameworks in which QE has a macroeconomic effect have been more firmly established. These frameworks typically deviate from the benchmark assumptions outlined above by incorporating more realistic frictions. The resulting body of literature has put forward several potential transmission channels through which QE may have an impact on financial conditions and the macroeconomy. Broadly, these channels can be categorised into three groups. First, those associated with policy "signalling". Second, those associated with the "portfolio balance channel." Third, those associated with market liquidity.[16]

It is important to note that there is no reason to expect these channels of QE transmission to be mutually exclusive. Indeed, it seems likely that each channel operates to at least some extent most of the time. All channels ultimately operate via an effect of asset purchases on long-term interest rates and hence monetary conditions and ultimately economic activity and inflation. There is no *a priori* reason why all channels should not operate simultaneously: why should the benchmark textbook model be misspecified in just one way? Moreover, it is widely accepted that there are several coexistent transmission channels of conventional monetary policy: why should QE be any different? As discussed below, what matters in practice is which channels are most important and whether there may be circumstances where some channels are likely to be particularly effective.

With this caveat in mind, it is nevertheless convenient to consider each channel in turn.

The 'signalling channel' was perhaps the most natural explanation for an impact of QE in the early literature, without substantial deviation from the baseline model.[17] While the precise mechanisms for the signalling channel are less well established in the theoretical literature, the explanation tends to centre on QE as a way to mimic a commitment by the policymaker to hold rates lower for longer than they otherwise would.[18]

15 This result can be viewed as an extension of a classic neutrality result of Wallace (1981), which demonstrates that the composition of public liabilities has no effect on equilibrium prices and quantities. As the title of Wallace's paper highlights, his results are in turn a variant of the Modigliani-Miller theorem (that the value of a firm is unaffected by the composition of its liabilities) applied to public sector liabilities.

16 There is relatively little theoretical literature on the role of reserves and money *per se* in transmitting the effects of QE. Aksoy and Basso (2014) and Reis (2017) present models in which QE operates via the increase in interest-bearing reserves held by commercial banks. An increase in reserves dilutes the overall risk of bank portfolios In Aksoy and Basso (2014), this occurs via a reduction in liquidity risk. In Reis (2017), additional reserves cushion the effects of an increase in sovereign default risk. Christensen and Krogstrup (2016) develop a framework in which changes in reserves matter for financial conditions via their effects on bank behaviour.

17 Indeed, Eggertsson and Woodford (2003) do not rule out the possibility of a signalling channel: "Open-market operations should be largely ineffective to the extent that they fail to change expectations regarding future policy; the conclusion we draw is not that such actions are futile, but rather that the central bank's actions should be chosen with a view to signaling the nature of its policy commitments, and not for the purpose of creating some sort of "direct" effects."

18 In theory, holding large quantities of long-term debt on its balance sheet exposes the central bank to interest rate risk, in principle creating an incentive to keep the short-term policy rate low to avoid balance sheet losses. Bhattarai, Eggertsson and Gafarov (2015) provide the clearest theoretical exposition of this channel. They show how the role of government debt as a state variable may influence the behaviour of future policymakers, building on the earlier insights of Eggertsson (2006) and Berriel and Bhattarai (2009). As noted in footnote 5, asset purchases decided by the MPC are undertaken by the APF, which is indemnified by HM Treasury. As such, interest rate risk associated with changes asset values is borne by the Treasury.

The ‘portfolio balance channel’ of large-scale asset purchases is described by Ben Bernanke as follows:

> [t]he so-called portfolio balance channel … [implies] that once short-term interest rates have reached zero, the Federal Reserve's purchases of longer-term securities affect financial conditions by changing the quantity and mix of financial assets held by the public. (Bernanke, 2010).

As such, the portfolio balance channel can be generated in any theoretical framework in which changes in the relative quantities of assets held by the public has an effect on financial conditions. Indeed, a macroeconomic role for QE via such effects has been established in a number of ways. Replacing the assumption of perfectly efficient markets with one of limits to arbitrage, market segmentation, or preferred habitats can generate downward sloping demand curves for individual assets. In turn, this means that changing relative asset supplies for the private sector through QE purchases will affect relative returns. For example, one approach is to include portfolio preferences, so that different assets are imperfect substitutes on account of their non-pecuniary properties (see for example, Brainard and Tobin (1963), Andres *et al* (2004), Chen *et al* (2012) and Harrison (2012)). Other strands of the literature incorporate portfolio adjustment costs (Harrison, 2011, 2017) or preferred habitats, in which investors might demand certain assets for specific – perhaps regulatory – purposes (Vayanos and Vila, 2009, 2020).

Frameworks in which some types of assets are more suitable for use as collateral imply that QE can affect the behaviour of leveraged investors by changing the composition of their balance sheets (Gertler and Karadi, 2011, 2013). Even when investors are rational and markets are efficient, generalising the form of investors’ utility functions can lead to a role for portfolio compositions in determining asset prices (King, 2015). A wide range of mechanisms have therefore been studied, all of which are consistent with a broad characterisation of the portfolio balance mechanism and many of which imply similar macroeconomic effects of QE.

A third potential channel of QE transmission is the liquidity channel. This channel is most often associated with addressing impaired market functioning in specific markets, which might otherwise lead to a substantial tightening in monetary conditions or disrupt the monetary transmission mechanism.[19] The liquidity channel can therefore operate in addition to those discussed above and is likely to be particularly relevant for the impact of QE in times of financial turbulence. The liquidity channel relies on the existence of a market or informational friction, which creates a role for central bank asset purchases in encouraging trading and reducing liquidity premia in a given market (Joyce *et al*, 2011; Haldane *et al*, 2016). This liquidity channel was important in the design of the Bank of England’s (relatively small) purchases of private sector assets in 2009 – which included commercial paper and corporate bonds. The aim was to provide confidence to investors and issuers that they could find buyers for these assets if they needed to sell quickly, without incurring an excessive price discount.[20]

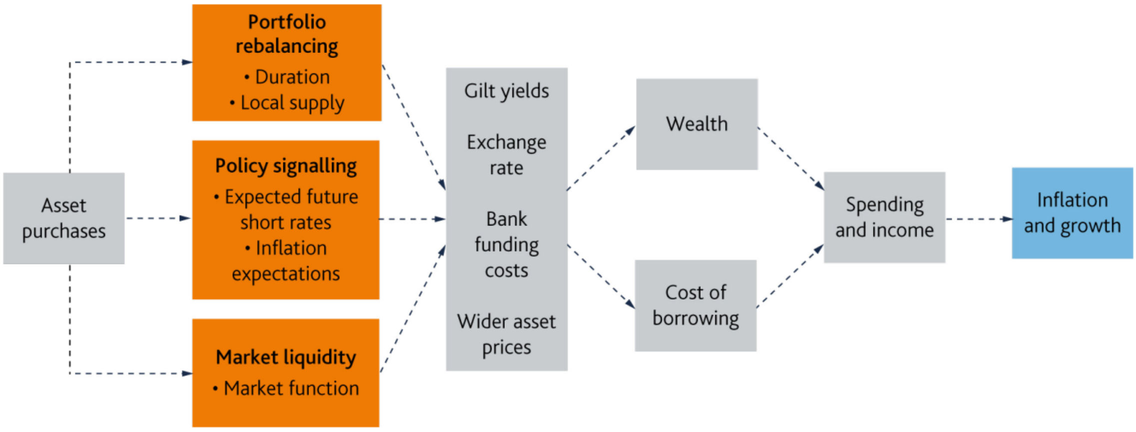
Figure 2 below traces the transmission of the portfolio rebalancing, signalling and liquidity channels to the wider economy. As discussed above, there is no reason to expect these channels to be mutually exclusive. Ultimately, each mechanism acts to lower longer-term interest rates. Associated with that, the cost of borrowing is reduced, funding conditions are eased and asset prices are stimulated, all very much akin to the transmission mechanism of a reduction in the short-term policy rate.[21] The result is that spending is stimulated, boosting GDP and pushing inflation – the ultimate objective – back towards its target.

19 See CGFS (2019) for a detailed discussion of the role of unconventional monetary policies – and within that asset purchases – in addressing disruption to the monetary transmission mechanism.

20 See Tucker (2009) and Fisher (2010).

21 See Benford *et al* (2009) for a summary of the range of potential QE transmission channels which were considered when QE was first launched in the UK.

Figure 2 Stylised QE transmission mechanism



Taken together, the growing body of research on the theoretical underpinning of QE means that – while there remains much more to learn – the state of knowledge has moved beyond Ben Bernanke's famous remark that "the trouble with QE is that it works in practice but not in theory".[22]

The effects of QE in practice

The other clause of Ben Bernanke's statement – that QE works in practice – is now supported by a rich body of empirical work, which has grown rapidly over the past decade. The review below draws out some of the key findings from that literature.[23]

There is broad consensus that QE programmes have been successful in lowering government bond yields, often by a considerable amount. This result has been established across multiple jurisdictions and using a wide range of different methodologies. For example, Gagnon (2016) collates estimates from 28 studies across the US, UK, Japan, EA and Sweden and finds an average reduction in 10-year government bond yields of around 70 basis points associated with a QE intervention normalised to 10 per cent of GDP. Similar surveys of the impact of QE on yields corroborate this finding – see for example Borio and Zabai (2016) and CGFS (2019). For the UK, estimates of the impact of QE1 and QE2 on 10-year yields range from 50-100 basis points (see for example Joyce *et al*, 2011; Haldane *et al*, 2016; and Christensen and Rudebusch, 2012).[24]

Beyond reduced government bond yields, the evidence suggests that QE programmes have also been accompanied by a more general easing in monetary conditions. CGFS (2019) assesses 37 studies internationally and concludes that "an extensive academic literature suggests that asset purchases influenced financial conditions markedly." The report also notes that private sector asset purchases can be particularly effective at easing credit conditions of the assets targeted. The UK's experience of the Corporate Bond Purchase Scheme in 2016 is consistent with that finding. For example, D'Amico and Kaminska (2019) find that the Corporate Bond Purchase Scheme (CBPS) reduced corporate credit spreads.

The evidence on the effects of QE on bank lending is relatively mixed. Some recent papers for the euro area and US find a material impact on bank lending from QE purchases (see for example Tischer, 2018, for the EA and Rodnyansky and Darmouni, 2017, for the US). In contrast, Butt *et al* (2014) find no evidence of a bank lending channel in the UK, arguing that the high churn in deposits created by QE

22 Bernanke (2014).
23 It is beyond the scope of this paper to provide a full survey of the empirical literature on QE. The review in this section seeks to highlight some of the themes from that literature, drawing heavily on the many existing excellent survey papers, notably Bernanke (2020), CGFS (2019), Gagnon (2016) and Haldane *et al* (2016).
24 In the UK, the QE1 and QE2 programmes totalled £325bn, around 20% of annual GDP at the time.

meant that they were not viewed as a stable source of funding. Giansante *et al* (2020) corroborate this finding for the UK in a recent study.

Empirical studies of the effect of QE have tended to focus on the 'first-round' transmission of QE to interest rates, financial market variables and asset prices. As Borio and Zabai (2016) note, "while the literature on the impact of unconventional monetary policies on financial conditions is vast, that on their effect on output and inflation is much more limited." This is unsurprising, as each step through the transmission mechanism – with the associated lags at each stage – makes it more difficult to credibly identify causal QE effects. Other events cloud the picture and the counterfactual is unknowable. An intraday event study can pinpoint QE's effects on yields, but is of no use in establishing the ultimate effects on GDP and inflation. Of course, it is these macroeconomic effects that are of most interest to policymakers.

To produce estimates of the macroeconomic effects of QE, some studies have taken estimates of the financial market impacts and applied them to standard macroeconomic models. These estimates assume that the transmission of QE beyond financial markets works in the same way as for conventional policy and are open to challenge on the persistence of the financial market effects of QE (discussed below). Other studies have attempted to identify QE shocks in a structural VAR setting, though such studies must contend with likely structural breaks around the time QE was introduced. On balance, studies that do attempt to trace out the macroeconomic effects of QE tend to find meaningful impacts on both GDP and inflation. For example, CGFS (2019) surveys 25 such studies internationally and finds positive effects overall on both output and inflation, while also acknowledging the uncertainty of those estimates.[25] Work by Bank of England economists suggest that the initial £200bn of QE in the UK may have pushed up on the level of GDP by a peak of 1.5%-2% and on inflation by 0.75%-1.5% (Joyce, Tong and Woods, 2011). Later work by Weale and Wieladek (2016) took an SVAR approach and found that both the US and UK's QE programmes may have raised GDP materially, with peak effects that are higher than most other estimates. Haldane *et al* (2016) expand this SVAR approach across a broader set of countries and episodes, finding that QE in the US and UK appears to have had both a positive and significant impact on both activity and inflation.[26]

It is important to remain humble when assessing the accuracy with which the full macroeconomic transmission of QE is understood. For example, Williams (2013) estimates that the uncertainty surrounding the estimated impact of QE on macroeconomic variables is at least twice as large as that for changes in interest rates. Borio and Zabai (2016) provide an apt summary in their survey: "The bottom line is that these results generally have to be taken with more than a pinch of salt. The more data-dependent methods rely heavily on unreliable extrapolation from previous relationships. And the more theory-based ones are better regarded as illuminating the mechanisms at work. There is clearly an effect, but its size and stability are quite uncertain."

Overall, while it is clearly difficult to estimate the 'per £ impact' of QE on the macroeconomy with great accuracy, QE appears to have offset at least some of the contractionary forces of the GFC in 2009 and several shocks since then. Asset purchases have been able to step in to provide significant support to aggregate demand, and in turn to the economy.[27]

Evidence of sustained QE transmission across time and space

Some QE studies challenge the overall body of evidence that QE can have a meaningful macroeconomic impact. As discussed in detail in Bernanke (2020), that challenge typically takes one of two dimensions

25 This CGFS (2019) meta study draws mostly on studies using DSGE and structural VAR models.
26 Haldane *et al* (2016) find macroeconomic impacts for the US broadly in line with other studies such as Chung *et al* (2011) and Baumeister and Benati (2013).
27 Broadbent (2018).

arguing either: i) that the impact estimates of QE have *diminished materially over time*, as additional rounds of QE have been announced in non-crisis settings; or ii) that the observed impact of QE on financial markets is only transitory, *lacking the persistence* to have meaningful macroeconomic effects. Both arguments warrant careful consideration and should temper any assumption that the effects of QE on activity and inflation are firmly established or immutable. Bernanke (2020) does, however, argue persuasively that neither critique is a knock-out blow for the ongoing effectiveness of QE. The supporting evidence is summarised briefly below, together with the related question of which QE transmission channels are supported by the available evidence.

Some studies have found diminishing effects of QE in later rounds – see for example Greenlaw *et al* (2018) and Krishnamurthy and Vissing-Jorgensen (2011). One possible explanation is that initial rounds of QE were particularly effective given the crisis state of financial markets (such "state-contingency" is discussed further below) or because of the one-off novelty impact of announcing a new tool. Other studies have observed that the effectiveness of QE may have diminished as long-term interest rates have fallen closer to their floor.[28] That may raise questions over the efficacy of QE in providing monetary stimulus on an ongoing basis, in more 'chronic' times, outside of crisis conditions.

However, diminishing observed effects of QE in later rounds need not suggest ineffectiveness. In particular, as QE becomes embedded in central bank reaction functions, anticipation effects clearly pose a significant challenge to event-study methodology, which relies on well-identified QE *surprises* (see Gagnon (2018)). Controlling for QE expectations helps to uncover an ongoing impact on gilt yields. In the Euro area, De Santis and Hadulla (2019) attempt to account for anticipation effects and find a 63 basis points impact on government yields from the ECB's introduction of its purchase programme in 2015. They argue this suggests an undiminished QE impact, compared to the typical QE1 effects estimated in the US and UK 5-6 years earlier.

Several other strands of literature identify a role for portfolio balance effects in ways which challenge the notion that QE became ineffective in later rounds. For example, one fruitful approach is to look at the *relative* moves in yields (for example of different maturities), in response to surprise announcements in the *mix* of asset purchases.[29] These studies typically find that yields on the assets towards which purchases were (unexpectedly) skewed fall relative to others, consistent with the 'local supply' effects of the portfolio balance channel. By cleanly identifying unanticipated QE effects on asset allocations, these studies challenge the reduced form observation that QE's impact diminished in later rounds. In a similar vein, other studies demonstrate differential impacts on the yields of assets depending on whether they are eligible for central bank purchases.[30] In an alternative approach, which also supports a role for the portfolio rebalancing channel, Joyce *et al* (2014) study the balance sheet response of insurance companies and pensions funds to QE and find evidence of a shift from gilt holdings towards corporate bonds.

There is also an active debate on whether QE has a persistent impact on financial conditions. An important challenge is whether the observed impact of QE on yields – often identified by looking at a tight event study window – is sufficiently persistent to have a meaningful macroeconomic effect.[31] It is possible that an observed change in yields is instead driven by relatively transitory effects, rather than a by more lasting portfolio balance or signalling mechanisms (see for example Wright, 2012). While this observation suggests macroeconomic estimates should perhaps be interpreted with some caution, a

28 See for example, King (2019) and for an early commentary Goodhart and Ashworth (2012). Borio and Zabai (2016) also survey this debate, concluding "views, therefore, differ. Our own assessment is that… there are bound to be limits on how far nominal interest rates can be reduced and risk spreads compressed."

29 See for example D'Amico and King (2013) and Cahill *et al* (2013) in the US and Banerjee *et al* (2014), Joyce and Tong (2012) and Meaning and Zhu (2011) for the UK.

30 See for example Di Maggio *et al* (2016), which finds a differential impact on MBS yields, depending on whether they were agency-backed and therefore eligible for the Fed's purchase programmes.

31 For a good summary of critiques/discussions on the drawbacks of event studies see: Vlieghe (2018).

growing body of research suggests that asset purchases led to substantial, long lasting reductions in long yields.[32] Several of the studies discussed above which consider surprises in the QE purchase mix also find persistent impacts on (relative) yields.[33] Bernanke (2020) reviews this literature in detail and also offers other evidence to support a more persistent QE effect. This includes the observation that QE purchases have affected "cross-asset" yields (i.e. yields of assets not being directly purchased) and also induced greater corporate bond issuance, both supportive of QE effects beyond immediate, asset-specific liquidity effects.

On balance, the literature provides evidence of ongoing QE transmission to the macroeconomy in later rounds of purchases and is supportive that at least some of the associated transmission channels are persistent. However, this need not suggest that *all* QE channels are equally powerful and persistent in *all* states of the world.

Unsurprisingly, the evidence is not clear-cut on precisely which QE transmission channels have operated in which circumstances. There are only a relatively small number of observed QE actions, making it hard to identify the overall impacts of those actions and harder still to ascertain the precise channels of transmission. This perhaps explains why different authors have placed differing weights on the relative importance of the main QE transmission channels.[34]

While the debate continues over the relative importance of each channel, the balance of evidence suggests that each has contributed to the overall effectiveness of QE. It seems likely that the three broad transmission channels have often operated together. As set out above, a number of strands of the literature credibly identify portfolio balance mechanisms in action. Other studies have found that QE impacts the path of expected interest rates, supporting the signalling channel.[35] The role for different channels will surely have varied depending on the precise nature of the QE programme, the jurisdiction and the economic context. Consistent with that, the recent experience of QE as a key part of the central bank response to the Covid crisis globally – and the unprecedented economic context in which that response was forged – will provide an important new evidence base with which to deepen our understanding of QE. This issue is revisited in Section 2 and prompts some early observations from the QE experience in the Covid crisis.

1.2 The role of reserves

The dominant component of the liabilities side of the Bank of England balance sheet – measured both in absolute terms and as the change over the past decade – is accounted for by central bank reserves (**Chart 2**). In large part, these reserves were created as a by-product of the QE operations analysed in Section 1.1.

Any QE operation, in which the Bank of England purchases assets (via dealers) from the non-bank private sector, will create central bank reserves on the asset side of commercial banks' balance sheets and deposit liabilities on the other side (as investors who have sold assets to the Bank deposit money with banks).[36] Similarly, the Term Funding Scheme, first introduced in 2016, is essentially a secured loan to the banking system and creates additional reserves and a liability to the central bank secured on the collateral taken by the Bank as part of the scheme.[37] The Bank was able to maintain interest rate control

32 See for example Ihrig *et al* (2018), which finds a cumulative effect of QE on 10-year yields of around 100 basis points persisting in the US out to 2015. See also Neely (2016), Swanson (2020), Wu (2014) and Coure (2018), Altavilla *et al* (2015) and Eser *et al* (2019) on the persistence of QE effects in the US and EA respectively.

33 See for example Cahill *et al* (2013) in the US and Banerjee *et al* (2014) for the UK.

34 For example, in the UK, Lloyd (2020) finds a larger role for the signalling channel, which is also emphasised in Vlieghe (2018), while Joyce *et al* (2011) attribute greater importance to the portfolio rebalancing channel. Similar debate is reflected in the US literature, with – for example – Bauer and Rudebusch (2014) emphasising the signalling channel and Gagnon *et al* (2011) putting more weight on portfolio rebalancing.

35 See for example, Bauer and Rudebusch (2014) and Farmer (2012).

36 As noted in footnote 11, QE purchases from the non-bank private sector are intermediated via dealers.

37 For more information, see Ginelli Nardi, Nwankwo and Meaning (2018) "The Term Funding Scheme: design, operation and impact".

despite the large increase in reserves associated with these policies by operating a 'floor' system, in which reserves were remunerated at Bank Rate.[38] This enabled policymakers to control both the price and quantity of reserves, achieving a particularly stable regime for market interest rates.[39]

Despite the large-scale creation of reserves as a result of these operations, the quantity of reserves *per se* is not a sufficient guide to the overall monetary policy stance.

If there is a quantity measure that provides an indicator of the stance of monetary policy then it arguably should be broad money or bank lending.[40] However, there is no mechanical link between the creation of reserves associated with the policy actions described above and the impact on lending or broad money. The modern banking system, in which loans create deposits, bears little resemblance to the textbook 'money multiplier' model in which commercial banks expand lending until a statutory reserve ratio is satisfied.[41] Reserves are therefore not a good corroborative indicator of the money and lending quantities of macroeconomic interest. Moreover, using the growth of deposits or lending as an indicator of monetary stance is itself complicated by the absence of a credible counterfactual against which the impact on deposits or lending can be measured.[42]

Despite the measurement of the scale of many post-GFC policy responses in billions of pounds, the quantity of reserves therefore does not provide a sufficient summary statistic for the stance of monetary policy. It is not the creation of reserves *per se* that provides stimulus to the macroeconomy. The creation of reserves is a by-product of these monetary policy operations, rather than the end in itself.

This is not to understate the importance of reserves themselves, in particular with respect to financial stability, broadly defined. By acting as a buffer to meet the demand for greater liquidity in the face of a loss of economic confidence, the creation of reserves can help to prevent a liquidity problem in financial markets becoming one of solvency in the wider economy. In these episodes, the central bank balance sheet can be used to rapidly inject liquidity in response to the confidence driven flight to quality or liquid assets that is often associated with such events.

To some extent, this principle dates back to the inception of modern central banking, typified in Walter Bagehot's description of the London Money Market in Lombard Street.[43] Bagehot famously noted that the Bank of England should lend 'freely' in a panic to calm conditions and indeed this dictum was a reasonably good description of the Bank's actions in the late 19th century to stem periodic crises.[44] The Bank Charter Act, which constrained the amount of notes that could be issued in proportion to gold, was repeatedly suspended in the mid-19th Century to enable the Bank to provide liquidity during periodic crises.[45] As Fisher and Hughes Hallet (2018) have argued, the potential to ease terms for central bank facilities in stress can act as an important macroprudential tool.

Indeed, the global financial crisis (GFC) of 2007-2009 saw many central banks revisit the Bagehot playbook. For the Bank of England, a key component of the crisis response was an expansion in the range of facilities available to provide liquidity to core financial institutions – for example, the Special Liquidity

38 See Hauser (2019) for further discussion of the floor system.
39 Borio and Zabai (2016) refer to this as the "decoupling principle".
40 See, for example, Friedman (1960).
41 The creation of remunerated central bank reserves (at an unchanged level of Bank Rate) do not in themselves provide more stimulus if banks are price setters and were already pricing their loans profitably off their funding costs. It is also unlikely that an expansion of reserves would provide benefits to banks that might be highly liquidity constrained given the deposits created in the operations are likely to be 'flighty' (see Butt *et al* (2014)). Given these arguments, one would not expect any 'money multiplier' effect of higher reserves on lending (see McLeay, Radia and Thomas (2014)).
42 For example, money growth remained relatively weak during QE1 but the policy may have increased money growth relative to an even weaker counterfactual (e.g. see Bridges and Thomas (2012)).
43 Bagehot (1873).
44 Anson *et al* (2017).
45 The Act was suspended in 1847, 1857 and 1866. See Anson *et al* (2017) for more detailed description of these crises and Sowerbutts *et al* (2016) for a description of the 1866 events.

Scheme (SLS) which exchanged Asset Backed Securities for highly liquid T-Bills and long-term repo operations provided reserves against a broader range of collateral. The Bank's interventions at the heart of the GFC were targeted at the banking system in particular, reflecting that the crisis stemmed from problems in that sector.[46]

Importantly, the surge in demand for liquidity during the GFC highlighted a structural shift in demand, as well as the need for a decisive central response to restore financial stability. With the benefit of hindsight, the potential roles for central bank liabilities in providing liquidity insurance to the banking system were perhaps underappreciated in the pre-GFC operating framework. The quantity of high quality liquid assets (HQLA) held by the banking system appears to have been insufficient before the GFC. Liquidity requirements introduced subsequently recognise this fact and enable a greater degree of self-insurance against unexpected shocks.[47]

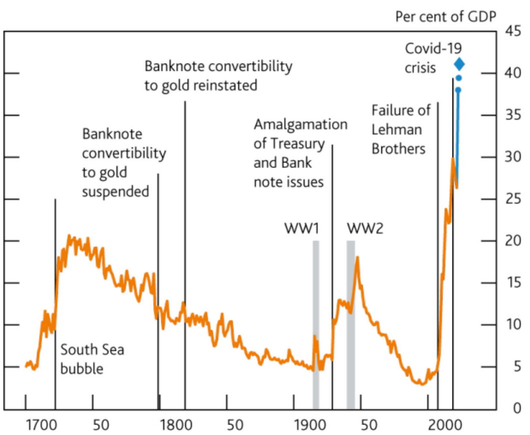
This suggests that the demand for reserves by the commercial banking system is likely to remain permanently higher than observed before the GFC.[48, 49] The structural increase in the demand for reserves therefore took place alongside the rapid expansion of the supply of reserves as the by-product of QE programmes, but was driven by different factors.

2: Lessons from the present

The Bank of England balance sheet has also increased substantially in response to the current crisis. The balance sheet expanded by almost a third in three months, and it is projected to reach just over 40% of annual UK nominal GDP by end-year (**Chart 3**). The balance sheet now stands at a level higher than at any point in its history.

Other central banks around the world have embarked on similar decisive balance sheet expansions (**Chart 3**), reflecting the global nature of this crisis. The most recent crisis therefore provides additional lessons on the role of the central bank balance sheet and its interaction with the broader policy toolkit.

Chart 3 The size of the Bank of England's balance sheet



Source: Bank of England, available here. Dotted line extends series to end-2020, assuming completion of current asset purchase programme. GDP over 2020 held fixed at end-2019 level.

46 Note that the SLS was not designed to finance new lending but to enhance the security that banks could use to borrow against. See John, Roberts and Weeken (2012). Notably, not all of the Bank's interventions involved the creation of central bank reserves – for example, the SLS provided newly created T-Bills. The GFC involved stress on core institutions (i.e. the commercial banks) stemming from less core markets (for example, asset-backed securities). Given sovereign debt markets were on the whole functioning smoothly, supplying these types of assets in collateral upgrade operations proved to be an effective means of alleviating stress.

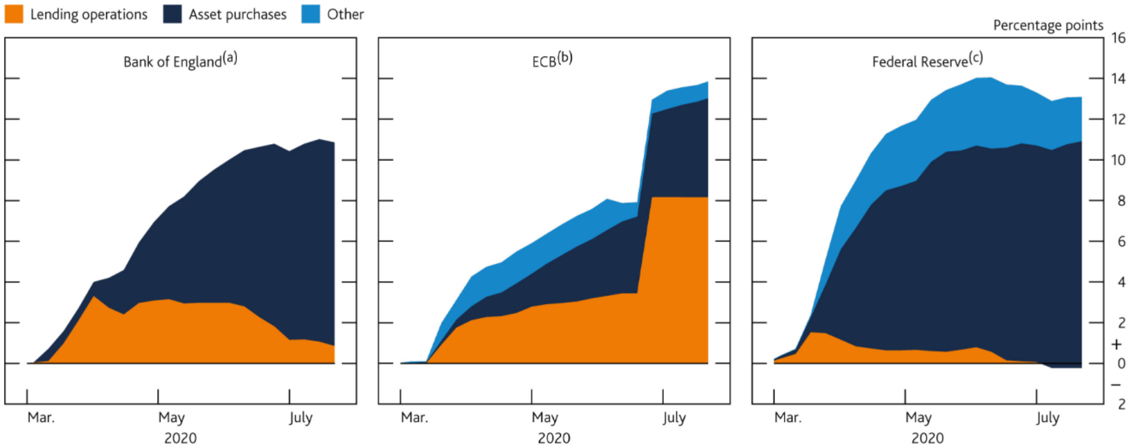
47 BIS (2013).

48 Greater demand for HQLA need not be satisfied by reserves alone. Eligible HQLA in the Liquidity Coverage Ratio is broader than this and the reserves component need only cover that part of firms' liquidity needs where intraday payments need to be made. However, in practice, there are a number of precautionary reasons why firms may prefer to hold a larger quantity of reserves than other types of HQLA.

49 As discussed in Section 3.2, the demand for reserves depends in part on the framework and terms on which those reserves are supplied.

Chart 4 Central banks have expanded their balance sheets decisively in response to Covid

Changes in components of central banks' balance sheets since the end of February 2020 as a proportion of 2019 nominal GDP in their home jurisdictions

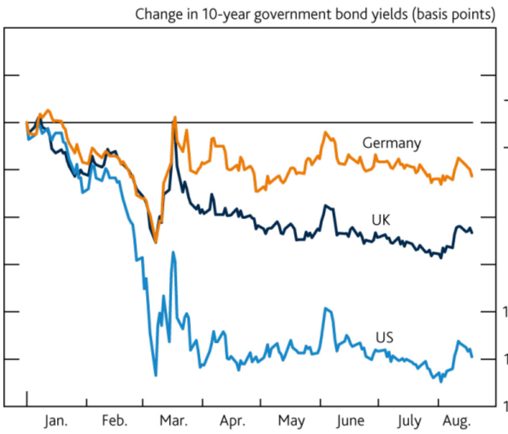


Sources: Bank of England, Bureau of Economic Analysis, European Central Bank, Eurostat, Federal Reserve Board, ONS and Bank calculations.

(a) Bank of England lending operations shown here: Indexed long-term repo, Contingent term repo facility, US dollar repo operations, Liquidity Facility in Euros, Term Funding Scheme and Term Funding Scheme with additional incentives for SMEs. Bank of England asset purchases shown here: Asset Purchase Facility and Covid Corporate Financing Facility.
(b) ECB lending operations: Lending to euro-area credit institutions related to monetary policy operations denominated in euro. ECB asset purchases: Securities held for monetary policy purposes.
(c) Federal Reserve lending operations: Repurchase agreements, Loans and Net portfolio holdings of TALF II LLC (less TALF II LLC Treasury contributions and other assets). Federal Reserve asset purchases: Securities held outright.

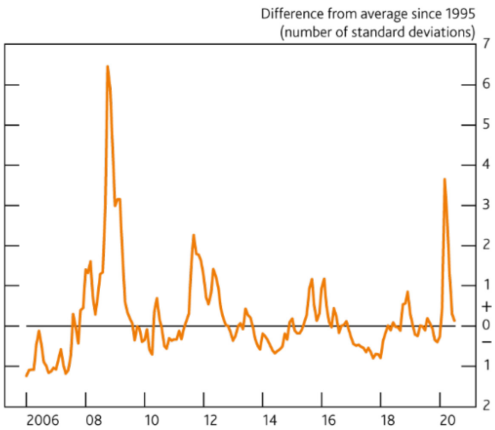
As the crisis unfolded in March 2020, a flight to safety in financial markets became an abrupt and extreme 'dash for cash': even safe assets such as long-term government bonds were sold to obtain short-term highly liquid assets.[50] Globally, the central bank response was decisive. The co-ordinated nature of the response is likely to have positively reinforced the effectiveness of domestic policies, given the potential significance of international spillovers in globally connected financial markets. These central bank actions were complementary to the substantial global fiscal response, which also helped to stabilise markets. Financial conditions have since eased and government bond yields remain lower than they were at the start of the year (**Charts 5** and **6**).[51]

Chart 5 Cumulative change in international government bond yields in 2020



Sources: Bloomberg L.P. and Bank calculations.

Chart 6 Global financial conditions



Sources: Bloomberg Finance L.P., Eikon from Refinitiv, IMF *WEO* and Bank calculations.

(a) Financial conditions indices (FCIs) estimated for 43 economies using principal component analysis and weighted according to their shares in PPP-weighted world GDP. The FCIs summarise information from: term spreads, interbank spreads, corporate spreads, sovereign spreads, long-term interest rates, equity price returns, equity return volatility and relative financial market capitalisation. An increase in the index indicates a tightening in conditions. Data are to end-July 2020.

50 See Hauser (2020) for an excellent discussion of "seven moments" of the Covid crisis in Spring and the policy response. See the May 2020 interim *Financial Stability Report* and August 2020 Bank of England *Financial Stability Report* for a detailed assessment of the financial system's performance during the height of the Covid shock.
51 Interim *Financial Stability Report*, Bank of England, May 2020.

To some extent, the lessons from the GFC meant that central banks were well prepared to design and implement large-scale balance sheet operations at pace in response to the unfolding Covid crisis. The central bank response can be split into two categories. First, tools that have been used since the GFC were extended, redesigned or recalibrated to reflect the needs of the current crisis. Second, innovative approaches were designed to target more directly the specific challenges of the Covid shock. As an illustration, the Bank of England's response is summarised below.

Familiar but recalibrated actions

On 11th March, Bank Rate was reduced by 50 basis points to 0.25%. An additional cut on 19th March took Bank rate to 0.1%, its current level. QE asset purchases of gilts and corporate bonds amounting to £300bn were introduced, first at a special meeting on 19th March and again on 18th June, to bring the total amount of asset purchases to £745bn. In both cases, the MPC noted that asset purchases were required to support economic activity and ensure a sustainable return of inflation to target.[52] The purchases announced in March were to be delivered as soon as operationally possible, to support improved market functioning. As discussed below, this was by far the largest and fastest QE programme ever launched in the United Kingdom.

The Bank also launched the Term Funding Scheme with incentives for SMEs (TFSME) in April 2020.[53] The Bank had used longer term funding programmes over recent years to reduce bank funding costs (the Funding for Lending Scheme, FLS) and strengthen the transmission of Bank Rate changes (the Term Funding Scheme, TFS). The launch of the TFSME built on past experience of the TFS, but also sharpened the incentives for lending to Small and Medium Sized Enterprises. That helped to ensure greater support for SME financing, given the uniquely challenging business conditions and cash flow disruption associated with the Covid shock.

Traditional liquidity operations also featured centrally in the Bank's policy response, ensuring that commercial banks could access liquidity on demand. Again, while these facilities were familiar to market participants, their terms were improved substantially to incentivise greater use. Hauser (2020) describes each aspect of the policy response in detail. In summary, key elements included:

- The internationally co-ordinated mobilisation of dollar swap lines with cheaper rates, longer terms and at a higher frequency. This was a crucial measure to support financial stability, given the rapid deterioration in dollar funding conditions in early March. Offshore dollar demand had spiked and shortages were leading to mounting selling pressure on dollar-denominated assets. The swap lines were able to decisively short-circuit this mounting market dysfunction.

- In the UK, the Contingent Term Repo Facility (CTRF) was launched on 24th March to enhance sterling liquidity insurance, alongside increased usage of the regular Indexed Long-Term Repo (ILTR) operation. The CTRF offered unlimited liquidity against a broad range of collateral at a spread of 15 basis points to Bank Rate. Overnight repo rates had risen to levels consistent with market dysfunction and this operation helped to rapidly bring repo rates back to more normal levels.

These measures represented a decisive deployment (and extension) of existing policy options, which were financed by the expansion of central bank reserves. The actions taken to inject liquidity on a larger

52 The minutes of the Special MPC meeting (19 March) and MPC meeting (25 March) noted that "An increase in the Bank's gilt purchases would help improve the functioning of the gilt market and help to counteract a tightening of monetary and financial conditions that would put at risk the MPC's statutory objectives, especially as the economy was now likely to be weakening very rapidly". The minutes of the June 2020 meeting stated that "members judged that a further easing of monetary policy was warranted to support the economy and thereby to meet the inflation target in the medium term".

53 The TFSME was formally announced on 11 March 2020 (see Market Notice) and opened for drawdowns on 15 April 2020.

and faster scale reflected the rapidly deteriorating conditions and the potential for the central bank balance sheet to be used in a countercyclical manner. These actions materially calmed conditions.

Innovative targeted action

In addition to more familiar central bank actions, the Bank also introduced a new facility to respond to the unique challenges posed by the pandemic. Working together with HM Treasury, this was designed to prevent Covid-19 from causing long-lasting economic harm.

On 17th March, the Covid Corporate Financing Facility (CCFF) was announced, a joint HM Treasury and Bank of England lending facility.[54] This facility was designed to directly support liquidity among non-financial firms that were rated investment grade prior to the Covid shock, through the purchase of Commercial Paper (CP) at pre-Covid rates.[55] This facility has allowed firms to bridge disruption to their cash flow in the Covid crisis and its reach has been substantial. The total amount of commercial paper currently outstanding with the scheme is around £17.5bn, issued by 65 businesses.[56] Moreover, over 200 businesses are currently approved for CP issuance to the CCFF, with a combined approved drawing capacity of over £80bn. Importantly, by providing these large non-financial firms with the insurance of ready liquidity, the CCFF has materially eased pressure on the credit facilities of the banking sector. That, in turn, frees capacity for the banking sector to support smaller firms, which do not typically use the CP market. The Treasury is responsible for the financial exposures of the CCFF and determines which firms are eligible to take part in the facility. The scheme itself is funded through the issuance of reserves, with the MPC's agreement.

Observations from recent policy actions

The impact of the Covid shock and the efficacy of the associated policy response is surely a key priority for research in the decade ahead. It is too soon to draw firm conclusions and it is beyond the scope of this paper to address each of the many important interventions in turn. However, some initial observations on the role of QE in the recent policy response may provide some helpful guides for future research. While QE is now a familiar tool from the post-GFC decade, the recent crisis offers a new lens through which to assess its role.

Observation 1: 'Going Big' with QE may be particularly effective at times of market dysfunction

One observation reinforced from the most recent rounds of QE is that the effects of asset purchases on financial conditions (and hence activity and inflation) may be state contingent. The recent experience lends additional – albeit tentative – weight to the argument that acting decisively with QE may be *particularly* effective in certain states, most obviously during times of widespread market dysfunction. For example, in such crisis conditions, liquidity effects may provide a more prominent channel of QE transmission.

Recognition of the potential state contingency of QE is not new, but research efforts on the topic should arguably be redoubled in light of the Covid experience. While the evidence discussed in Section 1 supports an important impact of QE on the macroeconomy on average, isolating the state contingency of those effects is naturally more challenging. Given the limited observations of QE policy actions worldwide, the available sample size to gather definitive evidence on the *variation* of QE impacts with respect to different economic states is extremely small.[57]

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54 For further information on the CCFF, see https://www.bankofengland.co.uk/markets/covid-corporate-financing-facility, which also has links to the latest usage data and a list of the firms that have borrowed.

55 The CCFF has some parallels to the CP purchase programme announced as part of the Bank's Asset Purchase Facility (APF) in early 2009, at the height of the GFC (see Fisher (2010)). The size and reach of the CCFF is, however, significantly largely than that previous programme.

56 Data as of close of business 19th August 2020, available weekly here. Total outstanding CCFF balance excludes sales and redemptions. A total of over £30bn of purchases have been made by the CCFF to date, including CP which has since rolled over or been repaid.

57 Moreover, identifying whether QE has a particularly important role in times of market stress is made challenging by the international interconnectedness of financial markets and the fact that these stress episodes typically feature multiple interventions (not just QE) by policymakers in multiple jurisdictions at very similar times.

Given the challenges of gleaning information from a small sample of case studies, the empirical evidence on QE state contingency is by no means definitive. Indeed, Bernanke (2020) surveys the pre-Covid literature and concludes that it is consistent with a relatively constant impact of QE across episodes.[58]

There are, however, theoretical and empirical arguments to support some QE state contingency with respect to the degree of market dysfunction.[59] To be clear, this is not to suggest that QE may *only* be effective in dysfunctional conditions, but rather to consider whether such conditions may make it *particularly* effective.

A useful starting point is to consider why QE transmission may be more state contingent than changes in the short-term policy rate.[60] The impact of Bank Rate on the macroeconomy may itself be somewhat state contingent (e.g. Tenreyro and Thwaites, 2016). For example, the sensitivity of activity to real interest rates may vary over the cycle and the role of expectational and confidence effects may also evolve. These potential state contingencies in the links between financial conditions and GDP also apply to the later stages of QE transmission. In addition, the early stages of QE transmission – from purchases to broader financial conditions – are influenced by a different set of financial market frictions. As set out below, these portfolio frictions are also likely to vary depending on the economic context, potentially in relatively fast-moving ways.[61] These effects could increase the extent to which the effects of QE are state contingent, relative to the short-term policy rate.

Both the portfolio balance and the market liquidity channels of QE transmission may depend intimately on the state of financial markets and so vary with the degree of market dysfunction. For example, as markets become more dysfunctional, arbitrageurs become more constrained, strengthening the role of portfolio rebalancing effects. Similarly, impaired market functioning may give rise to an increased role for a liquidity channel of QE, if liquidity premia are larger and more sensitive to intervention. Relatedly, increased risk aversion may strengthen the portfolio rebalancing channels of transmission, as it may lead assets with different risk profiles to be seen as less perfect substitutes (the 'local supply' channel) and increase the sensitivity of investors to changes in interest rate risk (the 'duration' channel). It also seems likely that the signalling channel of QE transmission will depend on the nature of the economic shock, becoming most powerful when there is "significant uncertainty about what the monetary policy response would be to a shock for which there is no precedent" (Vlieghe (2020)). Similarly, any role for QE announcements in bolstering confidence in a comprehensive policy response may also be amplified at times of market stress.

The experience of the GFC led policymakers to quickly acknowledge the potential link between the effect of QE and the degree of market dysfunction.[62] Haldane *et al* (2016) explore state contingency directly by estimating a regime switching model for the UK and US. In both countries, a high stress regime is identified from 2007 through to early 2010. The results suggest (primarily for the US) that the impact of QE on interest rates, GDP and inflation was significantly larger during the high stress regime, with the estimated QE impact on output doubling in size. Broadbent (2018) notes that state contingency is arguably "intrinsic to the effects involved" with QE transmission.

58 Bernanke (2020) sums up: "the research rejects the notion that QE is only effective during periods of financial disruption. Instead, once market participants' expectations are account for, the impact of new purchase programs seems to have been more or less constant over time, independent of market functioning, the level of rates, or the size of the central bank balance sheet."

59 Note that the focus of this section is on the role of QE in helping to *alleviate* market dysfunction. A separate set of studies focus on early concerns that large-scale central bank purchases could *create* market dysfunction by leaving a large footprint on financial markets and disintermediating the private sector (for a review, see BIS (2019)).

60 The greater potential for state contingency in the transmission of "unconventional" monetary policies is not limited to QE. For example, as set out in the Bank of England's August 2020 *Monetary Policy Report* the downside risks associated with the transmission of negative interest rates are likely to be higher when banks are concerned about losses on existing loans, because they may be more likely to ration new lending. In other words, the transmission of negative rates is likely to be dependent on the state of the financial sector. Such observations indicate that when considering how best to deploy the "new tools of monetary policy" (Bernanke, 2020), it will be crucially important to invest in understanding the state dependencies of each tool and how those dependencies compare and contrast. Indeed, the appropriate marginal tool of monetary policy could, in principle, depend on the economic context.

61 For further discussion, see Haldane *et al* (2016).

62 For the UK, see Dale (2010), Bean (2011) and Miles (2013, 2014).

From a theoretical perspective, state contingency of QE is consistent with the approach of Vayanos and Vila (2009), which catalysed much of the literature on portfolio rebalancing effects. This model relies on exogenous variations in agents' risk aversion: a key driver of that variation in practice could well be the state of the economy.[63] Models in which state contingency is more explicit have begun to emerge more recently. In Sims and Wu (2019), the efficacy of QE depends on the source of the shock: it is optimal to use QE to offset credit spread shocks rather than shocks to the equilibrium real interest rate. In a similar framework, Karadi and Nakov (2020) study the case in which the leverage constraints on banks that create a role for QE are occasionally binding, so that the role of QE depends on the state of the economy. Reis (2017) presents a framework in which QE efficacy depends on the level of (sovereign) risk at the time of implementation.

There is also some empirical support for the liquidity channel of QE being particularly important in times of market stress. For example, D'Amico and Kaminska (2019) find that – unlike in stable times – in periods of market stress, gilt QE lowered corporate bond yields by more than gilt yields. This compression of credit spreads, indicates that asset purchases might also improve trading conditions and capital mobility in indirectly targeted riskier markets. Also in support of a liquidity channel of QE transmission, Boneva *et al* (2020) find that the CBPS improved market liquidity: estimating a reduction in the effective bid-ask spread.

The market dysfunction experienced during the Covid crisis means that recent QE actions by the MPC – and globally – add valuable observations to a small sample when assessing the potential state contingency of QE. Looking across the five rounds of QE in the UK, there is some, necessarily tentative, evidence that the impact of QE has been largest at times of market dysfunction and illiquidity.

Chart 7 plots a measure of liquidity in the UK gilt market – the 10-year bid-ask spreads – and labels the first announcement of each QE round.[64] QE1 and the recent QE5 response to Covid stand out as the QE episodes launched at times of greater market dysfunction.

Bid-ask spreads remained elevated – around their 90th percentile in the historical distribution – throughout the depths of the financial crisis in 2009, when QE1 was announced. Importantly, however, market dysfunction was not centred in the gilt market during the GFC. There was substantially more acute stress in other markets (e.g. asset backed securities, bank funding and corporate bond markets).[65]

During the height of the recent Covid crisis, bid-ask spreads leapt to unprecedented levels, one of many indicators of rapidly deteriorating market function as the 'dash for cash' rippled through global financial markets.[66] This spike proved short-lived, with a rapid reversal following the introduction of the large and rapid QE5 purchases. In contrast, market function was relatively normal when QE2, QE3 and QE4 were announced (proxied in **Chart 7** by bid-ask spreads being at or around their average levels).

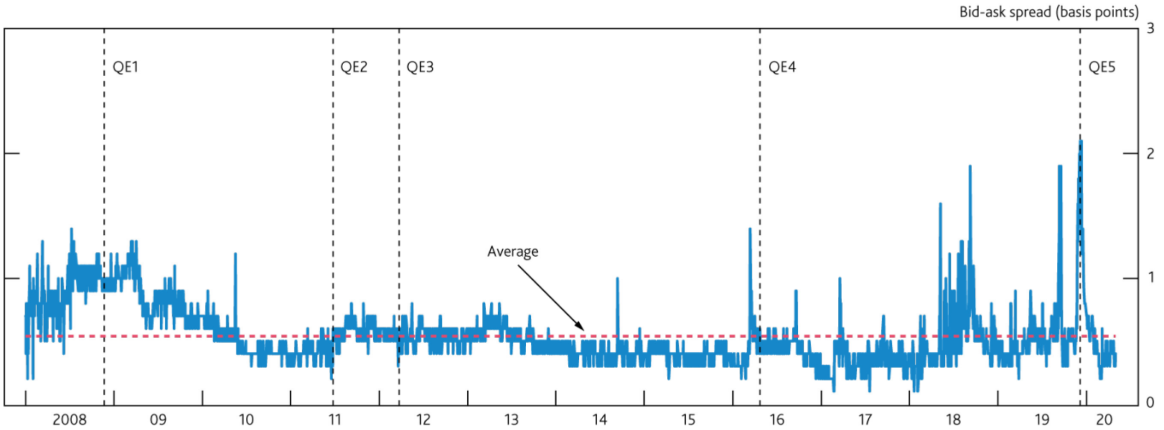
63 A generalisation of this approach could therefore generate state-contingent effects of QE. To the extent that market dysfunction can be interpreted as an exogenous shift in arbitrageurs' risk aversion, the link between QE transmission and market dysfunction is also implicit within that framework, albeit in a reduced-form way. Greenwood and Vayanos (2014) estimate time-varying risk aversion in terms of arbitrager losses.

64 Gilt bid-ask spreads are taken simply as one indicative measure of illiquidity – and potential dysfunction – in a typically deep and liquid market. Of course, market dysfunction is not the same as illiquidity and some markets are naturally more liquid than others, even in normal times. However, this measure provides a reasonable summary of broader market conditions and would typically be correlated with other measures of market stress, such as the degree of investor risk aversion.

65 Consistent with that, gilt market dysfunction was not one of the reasons cited for the MPC's QE1 intervention, Instead, dysfunction in the corporate credit markets was part of the motivation for the (relatively small) private sector purchases made in early 2009.

66 See Hauser (2020) for a detailed account.

Chart 7 Market liquidity in the UK gilt market in each QE episode



Source: Bloomberg L.P. and Bank Calculations. The simple bid-ask spread (i.e., the difference between the bid and ask bond yields) is used. This measure does not normalise for the possibility that the width of the spread might, in principle, depend on the shape of the yield curve. Benos and Zikes (2016), for example, divide the spread by the mid-price to account for this normalisation. This alternative measure shows a very similar pattern to the simple measure used here.

Disentangling the potentially state-contingent role of QE across these five UK episodes is necessarily very speculative. **Chart 8** gives one illustration. It captures three dimensions for each QE episode:[67]

First, the y-axis gives a simple indication of the impact of each round of QE on government bond yields. Specifically, it measures the change in 10-year gilt yields in a short (typically two-day) event window following each QE announcement. Second, the x-axis proxies for the degree of market dysfunction (ranging from 0 to 1) prevailing at the time of each QE announcement. This is based on the bid-ask spread series in **Chart 7**. Third, the size of the QE stock surprise associated with each announcement is illustrated by the size of each 'bubble.' This attempts to adjust for market expectations for QE at the time of the announcement.

Two episodes stand out for the relatively large reaction of gilt yields. First, the blue bubble, which is associated with the first QE1 announcement in 2009. Second, the yellow bubble, which is associated with the recent March 2020 announcement of a £200bn expansion to QE in response to the Covid crisis.

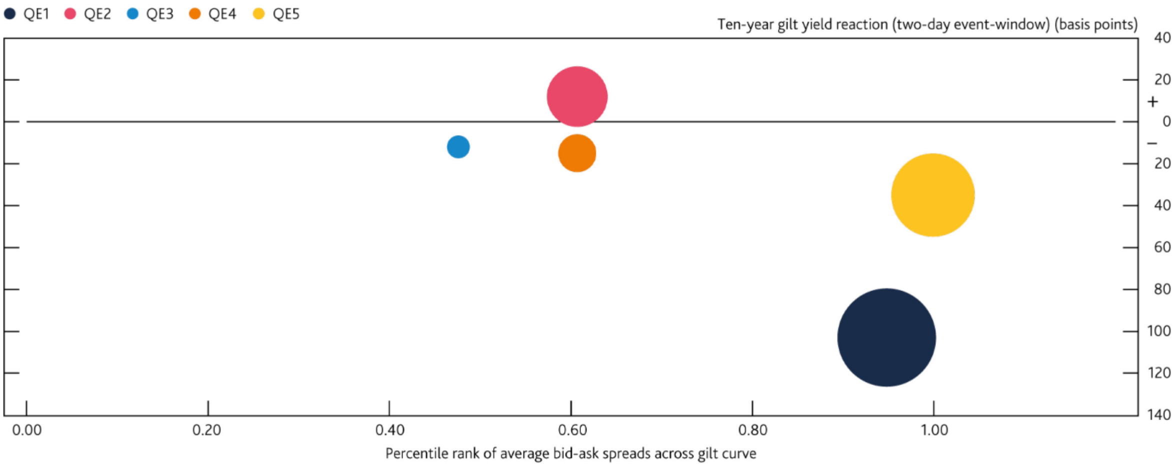
The economic circumstances in 2009 and 2020 were clearly very different. Moreover, the particularly large QE1 yield reaction may in part reflect the "sheer novelty value" (Broadbent, 2018) of the first UK QE intervention and the fact that the yield curve was higher a decade ago.

However, two common features across the QE1 and QE5 episodes did accompany these relatively sizeable QE impacts. First, the scale of QE relative to market expectations (the 'surprise') was large (these are the two biggest bubbles in **Chart 8**). Second, these surprises occurred at a time of significant market dysfunction, with bid-ask spreads towards the top of their historical range (the two bubbles are located furthest to the right in **Chart 8**).[68] Much more careful empirical assessment is required to tease out the relative roles of QE size and market dysfunction on the overall impact of policy. That research should be invigorated in light of recent experience. For the time being, these high-level observations are at least consistent with the contention that 'going big' with QE can be *particularly* effective at times of market dysfunction.

67 Simple illustrations such as **Chart 8** should clearly only be taken as – at best – indicative corroboration of the much more refined literature on QE impact and as the start of a conversation on the potential lessons from the most recent episode. In particular, each dimension of **Chart 8** is open to uncertainty and debate. First, the choice of event window to capture the gilt yield reaction to QE is open to challenge – too short and part of the response will be missed, too long and the price reaction will be contaminated by other events (particularly during a global crisis response). Second, it is difficult to establish a definitive measure of market expectations of QE prior to each announcement, making the "QE surprise" measure uncertain. Third, the appropriate measure of market dysfunction will vary depending on the nature of each episode – the gilt bid-ask spread is only one illustrative example.

68 A third common theme is that both were episodes of *global* crisis, which may mean that international spillovers from the global policy response are more likely to be captured, even in the relatively narrow gilt yield event windows studied.

Chart 8 The impact of UK QE on gilt yields, depending on market liquidity and the size of the QE surprise



Sources: Eikon by Refinitiv and Bank calculations.

Note: The y-axis proxies the gilt yield impact of each UK QE announcement. The measure used is the basis point change in the 10-year gilt yield in an event window following the announcement of each additional round of QE. A two-day event window was used for QE1-QE4. For the first QE1 announcement, the yield impact of both the February and March 2009 announcements are included, following Joyce *et al* (2011). For QE5, a shorter event window (until 08:15 on the day following the announcement) was deemed appropriate, given the substantial noise from other Covid developments and the international policy response. The x-axis gives the percentile rank of the average bid-ask spread across 5-year, 10-year and 30-year gilts at the time of QE announcement. The percentile is given relative to the distribution from 2008-2020. So an x-axis reading of 0.5 represents a median bid-ask spread, and a reading of 1.0 represents the highest bid-ask spread observed during the period. The size of each "bubble" is proportional to the size of the QE stock surprise in each episode. This surprise measure reflects Bank staff's best guess of the market expectation for the ultimate stock of QE prior to the announcement, based on available market intelligence and survey evidence. Only the first announcement of each new QE round is shown, rather than each subsequent extension within a given round of QE purchases.
QE1 = March 2009; QE2 = October 2011; QE3 = July 2012; QE4 = August 2016; QE5 = March 2020.

Observation 2: 'Going fast' with QE purchase pace may enhance effectiveness during periods of market dysfunction

The QE response to the Covid crisis – in the UK and globally – was unprecedented in its speed as well as its size. This observation prompts another important question for researchers and policymakers to disentangle over the decade ahead: what is the role of the *pace* of asset purchases in determining the efficacy of QE?

Thus far, the literature has tended to place most weight on the announced *stock* of assets to be purchased, rather than the *flow* of purchases over time, in driving the overall effect of QE.[69] It is, of course, challenging to disentangle the relative role of 'stock effects' vs 'flow effects', given that the stock and flows of QE purchases are connected by an accounting identity.[70] The following discussion considers whether there may be instances where 'going fast' with the pace of asset purchases may matter, over and above any information that pace contains on the eventual stock of QE. It is important to emphasise that these observations are intentionally speculative, with the objective of stimulating discussion rather than providing answers.

A potential role for the pace of asset purchases may be brought into sharper relief during times of market dysfunction. In such periods, risk aversion and liquidity premia are elevated and investors may be seeking to make substantial adjustments to their portfolios. By stepping in as an active buyer in such circumstances, central banks can potentially use QE to satisfy unmet demand for liquidity in the short term, as well as adjusting the composition of the private sector portfolio over the longer term. This liquidity channel may dampen dysfunctional market dynamics. The large-scale, synchronised liquidation of portfolios might otherwise lead to an amplified fall in asset prices and hence a further tightening of the constraints on leveraged investors. That in turn could lead to broader tightening in financial conditions, higher effective interest rates for the macroeconomy and ultimately weaker aggregate demand via financial accelerator mechanisms.

69 See, for example, D'Amico and King (2013) for an empirical investigation. From a theoretical perspective, the premise underlying the portfolio balance channel is that QE works by changing the relative supply of private sector assets – a stock concept.

70 By definition, the total stock of assets purchased is equal to the sum of the flows of purchases over time. Stock effects are generated by changes in the current and future expected stock of assets to be purchased by the central bank. Flow effects are those which occur as a result the central bank being an active participant in the market and the act of purchasing the assets.

Of course, the observation that QE pace may be particularly relevant at times of market dysfunction links directly back to the observation that the efficacy of QE may be state contingent. Given the limited sample size, it will clearly be very hard to identify the respective roles for 'going fast' versus 'going big' in determining the overall effectiveness of QE during times of market stress.

One potentially helpful starting point is to consider that the overall stock of QE is always calibrated to deliver the required stimulus to meet the inflation target, given prevailing monetary conditions. In "normal" times (when there is no market dysfunction), it seems plausible that this is all that matters: it is the QE stock that determines the overall reduction in long-term interest rates and hence the degree of monetary stimulus. In such circumstances, a given (surprise) announcement of QE purchases would impart very similar stimulus, regardless of whether those purchases were completed within, say, three, six or nine months. Even in times of market stress, the announced stock of purchases would continue to determine the degree of stimulus via the usual QE transmission channels.[71] The appropriate choice of the stock of purchases would, as always, be calibrated to meet the inflation objective.

However, in times of market stress, there may be an additional role for a rapid purchase pace, in preventing a counterfactual – and very undesirable – *tightening* in prevailing monetary conditions. By 'going fast' in implementing the announced stock of purchases in stressed conditions, the liquidity channel of QE may prevent the sort of escalating dysfunction outlined above. In contrast, an equally-sized stock of announced QE purchases, implemented at a slower pace, may be insufficient to contain such dysfunctional dynamics. Other things equal, unchecked market dysfunction would ultimately depress spending and inflation. By delivering the required monetary stimulus in a timely manner, rapid QE pace in times of market dysfunction may therefore have a positive spillover effect on financial stability, broadly defined, when it is most needed. This could help to contain the size of the eventual shock to the macroeconomy that monetary policy ultimately must address.

This narrative for the potential role of QE pace in helping to stem escalating market dysfunction was applicable to the 'dash for cash' dynamics, which rapidly overtook the global financial system in March. As outlined in Hauser (2020), financial conditions evolved extremely quickly during this tumultuous period, as markets attempted to process the Covid shock. A spike in demand for liquidity led to synchronised selling – including of the highest quality government assets – as market participants sought cash to meet rapidly evolving obligations and required portfolio adjustments. This dysfunction spread to the gilt market, with selling pressure driving yields up sharply in the days leading up to the MPC's vote to extend QE by £200bn on 19th March.

The MPC made the decision in March to 'go fast' as well as to 'go big' with QE in response to the Covid shock and associated market dysfunction.[72] The additional £200bn of asset purchases were to be made at the maximum achievable pace consistent with improved market functioning. This represented a step-change in QE pace, in comparison with previous rounds. In the weeks that followed, purchases were made at a rate of around £13.5bn per week, more than double the pace of QE1 purchases. That decision was consistent with the observations above that QE may be more effective in states of market dysfunction and – at such times – the pace of purchases may provide an important additional effect of QE transmission.

The impact of this announcement was decisive, with yields falling back sharply and market functioning measures quickly normalising (**Chart 7**). It is impossible to know how market conditions would have responded had the MPC not acted. It seems plausible, however, that spiralling dysfunction would

71 That is, those discussed in Section 1.1.

72 The minutes of the March 2020 meetings noted that "An increase in the Bank's gilt purchases would help improve the functioning of the gilt market and help to counteract a tightening of monetary and financial conditions that would put at risk the MPC's statutory objectives, especially as the economy was now likely to be weakening very rapidly".

ultimately have led to a significant tightening in monetary conditions. In this sense, the observed yield reaction to QE5 in March (**Chart 8**) may only capture part of the benefit of the policy. It cannot capture the counterfactual tightening in conditions that was avoided. Similarly, since they were announced simultaneously, it is impossible to prove whether the rapid pace of QE purchases had an important role to play over and above the large surprise to the stock of QE announced in March. It seems likely, however, that by ensuring that the Bank was a sizeable active buyer during the height of the 'dash for cash', the pace of MPC purchases played an important role.

By June, the MPC judged that a further £100bn extension of the stock of QE was necessary to deliver macroeconomic stimulus consistent with meeting the inflation target. Market functioning had materially improved by this point, such that the positive spillover effects of a rapid purchase pace had likely subsided. Consistent with that, asset purchases were implemented at a slower pace relative to March, and more in line with other recent QE rounds.[73] This approach is consistent with the logic outlined above, in which the stock of QE is calibrated to deliver the inflation target, given prevailing monetary conditions, with a more limited role of QE purchase pace in more 'normal' market conditions.

The global QE response to Covid has been similarly robust (see **Chart 4**) and rapid purchase pace has been a common feature. Internationally, there was a clear emphasis on the importance of preventing an undesirable tightening in financial conditions that would otherwise disrupt monetary transmission. Some central banks deployed "open-ended" variants of QE, or programmes tied to the evolution of the economic outlook, to reflect that.

The Fed, for example, launched an open-ended asset purchase programme in mid-March 2020. This included purchases of Treasury securities and agency mortgage-backed securities "in whatever amounts needed" to support monetary policy transmission.[74] The pace of planned Treasury purchases was dramatically increased at the outset of the programme, which reached a peak of $75bn per day (and over $300bn per week) for the first few weeks. For context, the Fed's initial round of Treasury Purchases in 2009/10 was at a planned pace of $30bn per month. Since the improvement in market functioning, the planned Treasury purchase pace has reduced significantly to around $80bn per month more recently.

The ECB launched the Pandemic Emergency Purchase Programme (PEPP) in March 2020 with an initial target stock of €750bn, which was later extended in March to €1,350 billion. The ECB's communications have noted that the PEPP is a "non-standard monetary policy measure" to counter the risks to the monetary policy transmission mechanism and inflation outlook. The purchase pace was noted to be relatively steady, though with some relative flexibility in approach compared to previous QE rounds incorporated.[75]

The Bank of Japan also took an open-ended approach as part of their Covid response measures. With regards to the asset purchase and yield-curve targeting policies that were announced in April 2020, it was noted that the intention was to *'…purchase a necessary amount of JGBs without setting an upper limit so that 10-year yields will remain at around zero percent'*.[76]

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73 Following the MPC's June extension to QE, purchase pace was moderated from around £13.5bn per week to around £6.9bn per week and again in August to around £4.4bn per week.

74 For example, in a recent speech Fed vice-Chair Clarida noted: *'… we launched a program… in whatever amounts needed to support smooth market functioning, thereby fostering effective transmission of monetary policy…'*.

75 While the PEPP is not unlimited in size, certain conditions applied to previous programmes have been relaxed in order allow the flexibility to make large-scale interventions in particular bond markets. For example, for the purchases of public sector securities under the PEPP, the benchmark allocation across jurisdictions will be the capital key of the national central banks. At the same time, purchases will be conducted in a flexible manner. This allows for fluctuations in the distribution of purchase flows over time, across asset classes and among jurisdictions. More information on the PEPP can be found here.

76 See Enhancement of Monetary Easing, 27 April 2020, Bank of Japan.

The globally co-ordinated nature of the monetary response to the Covid shock is likely to have compounded its effectiveness, given the international spillovers through the financial markets. Decisive action that was responsive to the degree of market dysfunction was a unifying theme.

Taken together, the first two observations from the QE response to Covid are at least consistent with the idea that in some (dysfunctional) states of the world, it may be particularly effective to 'go big' and to 'go fast' with QE. It is clearly a research priority to extend the body of evidence on the existence and nature of state contingency and the implications for optimal policy strategy. Section 3 provides some speculative analysis of the potential implications for central bank balance sheets in the future.

Observation 3: The role of QE may depend on where in the system liquidity stress originates

A third observation from the Covid crisis regards the manner in which the policy responses reached the parts of the financial system experiencing the liquidity shortfall. As described above, the turbulence and uncertainty associated with the rapidly deteriorating outlook in March prompted a large group of investors to suddenly increase their demand for 'cash' (for example, to settle margin calls).[77] That led to widespread sales of assets, including gilts. The MPC's asset purchases provided liquidity to gilt market investors: those investors were able to exchange their gilts for credits to their deposit accounts with commercial banks ('cash'). Outright QE purchases therefore satisfied the demand for liquidity from non-bank investors that were driving the 'dash for cash' and the associated market dysfunction. In contrast with the GFC, the banking sector was not driving the demand for extra liquidity in this instance.

Vlieghe (2020) highlights that the central bank can play an important role in breaking the feedback loop between market stress and the economic outlook, given its unique capacity to provide aggregate liquidity to the market. Central banks can purchase assets (via dealers) from the market participants that are experiencing a spike in liquidity demand, inducing them into distressed selling. These purchases can therefore provide liquidity where it is needed the most, preventing amplification mechanisms (such as fire sales) worsening market dysfunction. Central bank asset purchases are ultimately settled through the banking system and accounted for by an increase in central bank reserves.[78]

The potential role of QE purchases in directly addressing liquidity shortfalls in the non-bank finance sector offers a somewhat different perspective on QE transmission, compared with previous episodes. Implementation of QE in the United Kingdom has been designed to ultimately target purchases from the non-bank private sector.[79] Indeed, during the GFC, one rationale for QE was to 'go around the banking sector', by lowering long-term rates and easing corporate credit market conditions, at a time when the banking sector was entrenched in balance sheet repair (Dale, 2010). One channel through which QE eased monetary conditions was by replacing longer-term assets with cash (intermediated via reserves), triggering the portfolio rebalancing mechanisms discussed in Section 1.1.

As discussed in Section 1.2, the creation of reserves that accompanied the early QE programmes coincided with an increase in demand for liquidity by the commercial banking system. But QE was designed a decade ago to impart monetary stimulus, rather than with an explicit view to address increased liquidity demand from the banking sector. The latter could be regarded as a positive spillover for financial stability, broadly defined.

This historical perspective gives useful context when assessing the role of QE in the Covid crisis. The role of QE remains to deliver the appropriate macroeconomic stimulus to achieve the inflation target. But the

77 See Hauser (2020) and Cunliffe (2020) for an anatomy of this turbulent period. The August 2020 *Financial Stability Report* assesses the performance of market based finance, as well as the banking sector, during the height of the crisis.

78 As Vlieghe (2020) notes, this may also have important aggregate liquidity implications, as the level of excess reserves may determine banks' willingness to provide liquidity in different markets (see Correa, Du and Liao (2020)).

79 In the sense that non-banks are the 'ultimate' sellers of gilts: see footnote 11.

recent experience raises an important question about the extent to which QE can – and should – provide another positive spillover for financial stability, by backstopping the liquidity of market-based finance. The comprehensive review of the provision of market-based finance in light of the Covid shock, launched by the Financial Stability Board (FSB) with the full support of the Bank of England's Financial Policy Committee, will provide invaluable new evidence to inform an assessment of this question.[80]

3: Lessons for the future?

The lessons from the past and present illuminate the key role of the central bank balance sheet in implementing policies to achieve both monetary and financial stability. This section considers potential implications of these lessons for the future conduct of policy and the operational framework that may best support it. The exploration of these wide-ranging issues is necessarily preliminary and somewhat speculative: it is intended to encourage further research and debate on these topics.

To focus the discussion, two potential implications are explored in some depth.

First, past experiences suggest that the central bank balance sheet should typically adjust in a countercyclical manner, for both monetary policy and financial stability purposes. In particular, recent experience suggests that it may be appropriate to put additional weight on the potential for QE to be particularly powerful in some circumstances when considering some aspects of balance sheet adjustment for monetary policy purposes. Doing so could influence the judgement on the appropriate policy mix (between the short-term policy rate and QE) during a policy normalisation process. There would seem to be substantial gains to be made from further research on this question.

Second, it is important that the operational framework is designed in a way that supports a countercyclical balance sheet. The steady-state framework outlined in Hauser (2019) provides this support by relaxing the currently tight link between the level of reserves and the stock of asset purchases chosen for monetary policy purposes. Moreover, thought experiments using this framework demonstrate its potential to support countercyclical balance sheet adjustment for both monetary policy and financial stability purposes.

Each issue is considered in turn.

3.1 The central bank balance sheet as a countercyclical policy tool

Policy actions taken for both monetary policy and financial stability purposes will typically imply that balance sheet adjustments are countercyclical. However, the frequency of balance sheet adjustments for these purposes may be somewhat different.

Balance sheet interventions that are directed purely to financial stability objectives are often targeted and short-term. There is no purpose to the balance sheet expansion once a period of dysfunction has been resolved – the central bank's disintermediation of the market should cease and allow market discipline to set price discovery. Such actions have driven the Bank of England's balance sheet in a countercyclical direction, over relatively short periods of time.

There are case studies for such interventions in illiquid markets during both the GFC and the Covid-19 crisis. During the GFC, the Special Liquidity Scheme was targeted at improving the UK banking system's liquidity through collateral upgrade transactions exchanging illiquid Asset-Backed Securities for highly

80 August 2020 *Financial Stability Report*.

liquid T-bills.[81] The Bank's total liquidity provision reduced significantly between 2010 and 2012 as SLS was repaid (**Charts 1** and **2**).

Looking at the most recent crisis, the Bank's provision of short-term liquidity to the banking system acted in a similar fashion. For example, the Contingent Term Repo Facility (CTRF) was introduced in response to evidence of money market pressures during the March 'dash for cash' as well as increased usage of the regular Indexed Long-Term Repo (ILTR) operation. As conditions normalised, participation declined, drawdowns were repaid and the CTRF was withdrawn with little concern. In its peak week, the Bank supplied close to £34bn of liquidity via targeted facilities during the 'dash for cash', most of which has since been repaid.[82] This aligns with the experience of the Federal Reserve where the balance sheet has reduced from its peak as temporary liquidity extensions have been repaid. It is likely that the increase in reserves supplied via QE has also helped satisfy the liquidity needs of the banking system.

Turning to monetary policy, the notion that the conventional monetary policy stance should move with the economic cycle, with short-term interest rates falling in recessions and rising in booms, is familiar.[83] Since asset purchases represent a policy loosening, similar reasoning suggests that QE policies should generate countercyclical changes in the balance sheet.

However, the case that monetary policy operations should give rise to a counter-cyclical balance sheet is less well explored. In part that is because policy actions that give rise to large changes in the balance sheet have become commonplace only relatively recently.

The specific question explored here is whether the particular form of state contingency explored in Section 2 has implications for the conduct of QE and hence for the balance sheet. The observations in Section 2 suggest that, in periods of market dysfunction, liquidity effects may provide a significant additional channel to QE transmission. The consideration here is whether the choice of QE (scale and pace) may be influenced by the ability of the policymaker to 'go big' and 'go fast' in the event of a *future* episode of market dysfunction. Other things equal, a reduction in the stock of assets held on the balance sheet provides more space for large and rapid purchase programmes in the future.

Under what conditions might these considerations influence the appropriate behaviour of QE policy?

Standard and familiar arguments demonstrate that monetary policymakers should err towards stimulating the economy when nearing the exhaustion of policy space. In other words, policymakers should resist the temptation to 'keep their powder dry' in order to provide space for further stimulus at a later date.[84] The logic is simple: holding back stimulus in the near term will weaken the economy with certainty, whereas the benefits of applying that stimulus later will only be reaped in the event that it is implemented.

However, the analyses on which these arguments are based do not account for the possibility that the effects of some policy instruments may be state contingent. A stylised analysis in Appendix A explores the implications of state contingency using a simple macroeconomic model incorporating, in a stylised way, some of the relevant features. In particular, the analysis considers a case in which there is a probability that a future 'crisis' will hit the economy. In the event that a crisis occurs, the *pace* of asset purchases as well as the stock of purchases matters for the overall macroeconomic effect. These

81 John *et al* (2012). Other facilities, such as long-term repos with an extended collateral set, provided broader liquidity support. These operations expanded the balance sheet and were subsequently repaid. However, the reserves supplied in these operations were to a large extent replaced by QE purchases.

82 This figure includes dollar funding supplied via the Bank's swap-line arrangement with the Federal Reserve Bank of New York converted to sterling using the exchange rate as at 30th March 2020.

83 There is a large literature documenting the countercyclical *effects* of unanticipated changes in short-term policy rates (see for example, Christiano, Eichenbaum and Evans, 1999; Bernanke, Boivin and Eliasz, 2005; Boivin, Kiley and Mishkin, 2010; Ramey, 2016).

84 See, for example, Eggertsson and Woodford (2003) and Evans *et al* (2016).

assumptions are broadly consistent with the idea that QE may be particularly effective in times of market dysfunction.[85]

Bearing in mind the usual caveats associated with such a simple exercise, the results suggest that the conditions under which conserving future policy space would affect the stance of policy are somewhat extreme. There must be a sizeable probability of a substantial crisis event and the extent of the state-contingent QE effects must be very large. These results suggest that while there may be theoretical cases in which preservation of future QE policy space could influence the overall stance of monetary policy, they may be unlikely to prevail in practice.

So the stylised example in Appendix A, and conjectures based on it, are at best indicative thought experiments and are far from reliable prescriptions for practical policy. Indeed, a simple observation provides a challenge to the analysis. If the state-contingent effects of QE are driven by the need for gilt holders to exchange their gilts for deposits, then it must always be possible for the central bank to purchase more assets. The very fact that gilt holders own gilts that they want to sell provides the opportunity for the central bank to buy. This logic suggests that preservation of future QE policy space may only become an issue if the central bank owns an overwhelming share of the stock of gilts. On the other hand, beyond some point there may be financial stability consequences of increasing the stock of gilts held by the central bank, since doing so deprives the private sector of safe and typically liquid assets (see Section 3.2). In that event, investors have fewer liquid assets available to sell in a stress.[86]

The likelihood that space for future QE becomes a relevant factor depends in part on the behaviour of monetary policy. If the unwind of previous QE does not begin until the policy rate reaches some threshold, then negative shocks that arrive before the policy rate has reached the threshold will push it back to the lower bound and (in some cases) necessitate additional QE. Such extreme persistence in the stock of QE could lead to a ratcheting up of the stock of assets held over time.[87] Such an effect may be more likely if the equilibrium real interest rate remains low for a prolonged period.[88]

These considerations suggest that the potential state contingency of QE may have implications for balance sheet normalisation. Indeed, while a full analysis is beyond the scope of this paper, the same type of considerations studied in Appendix A may provide a greater motivation for tightening monetary policy by unwinding QE, rather than raising the policy rate when – and only when – the time comes for the stance of policy to start normalising.[89] That is, if it is possible to set the appropriate stance of policy using alternative combinations of the policy rate and QE, a combination that provides more space for future QE may be preferable, other things equal.[90]

In practice, policymakers must take a judgement on the appropriate stance and mix of policy instruments, based on a careful assessment of economic theory, empirical evidence and practical

85 As described in Section 2, the most recent 'dash for cash' involved stress in core markets (sovereign debt markets) which affected less core institutions (the shadow banking system). In that context, outright purchases of safe assets had a powerful effect in providing cash liquidity beyond the banking system.

86 A range of factors are likely to influence the space for future QE operations. Most obviously, the supply of the relevant assets, via government debt issuance, will affect the total quantity of assets, other things equal. To the extent that an increase in government debt reflects a fiscal response to a shock that weakens the outlook for growth and inflation, the underlying shock would also likely require a monetary policy response. In that case, the net effect on future policy space is less clear cut.

87 Again, the likelihood of such an effect depends on the existence and nature of state-contingent QE effects. In a framework without such effects (for example, Harrison, 2012) the appropriate policy mix can be brought about by many alternative combinations of the policy rate and QE. A ratcheting up of the balance sheet would merely be a consequence of a sufficiently long sequence of negative shocks and would have no implications for the capacity or otherwise of policy to offset future shocks. In the presence of the type of state-contingency discussed in Section 2, a ratcheting up of the balance sheet is more likely in the event that the policymaker must 'go big' and 'go fast' to respond to crisis shocks before previous QE programmes have been at least partially unwound.

88 Estimates of the equilibrium real interest rate have continued to fall over time and projections of future equilibrium real rates have remained persistently low (see, for example, the August 2018 *Inflation Report*).

89 The nascent theoretical literature examining models in which QE has state-contingent effects is suggestive of similar types of effect. For example, although the nature of state contingency is different to the one considered here, Karadi and Nakov (2020) find that the optimal timing of QE may be influenced by the required scale of future asset purchases.

90 In the absence of the type of state-contingency considered here, analogous arguments against 'keeping your powder dry' would apply to decisions about the appropriate policy mix during policy normalisation. If QE and the policy rate are sufficiently close substitutes, the policy mix to deliver the appropriate stance is irrelevant. Unwinding QE purely to create space for future asset purchases is not desirable.

considerations. This approach has underpinned the MPC's periodic assessments of how QE may be unwound, when the appropriate time comes. The latest assessment, from June 2018, states that the balance sheet should be unwound at a gradual and predictable pace, allowing reserves to fall back to a level demanded by commercial banks as evidenced through participation in regular repo operations.[91] The MPC judged that it would be appropriate to ensure that Bank Rate had risen to around 1.5%, before beginning to unwind the balance sheet. The threshold of 1.5% was viewed as a level from which Bank Rate could be cut materially (or raised further) as necessary. This approach allows Bank Rate to be used as the primary instrument to set the stance of monetary policy, in response to shocks in either direction, while gradual and orderly balance sheet unwind continues.

As noted, these judgements factored in the available theory, evidence and practical considerations. While some simple theoretical models suggest that it is optimal to unwind QE as soon as, or even before, the policy rate is raised from the effective lower bound, these results are driven by particular assumptions.[92] Some of the practical considerations that were important influences on the MPC's judgement are discussed by Broadbent (2018). One consideration is that Bank Rate is a more flexible instrument that can be adjusted more nimbly to shorter-term macroeconomic shocks. Another is the recognition that the effects of QE may be state contingent, in various ways.[93]

The discussion above suggests that some additional considerations may be relevant. It does not, however, constitute the foundations of an alternative strategy for balance sheet unwind, when the conditions warrant it. The logic and evidence that supported the MPC's June 2018 assessment remain valid. However, the particular form of QE state-contingency explored in Section 2 may be a relevant additional factor to inform future assessments of the withdrawal of monetary stimulus. The question of the appropriate policy mix during a normalisation process may therefore be more nuanced than had been previously thought.

3.2 Implications for the design of the operational framework

As noted in Section 3.1, both monetary policy and financial stability considerations suggest countercyclical movements in the central bank balance sheet. However, the effects on the balance sheet of policy actions to support financial stability may operate over different time horizons to the effects of monetary policy operations. Continuing to look to the future, it is important to ensure that the operational framework supports the ability of the balance sheet to adjust for both monetary policy and financial stability purposes.

The following discussion first outlines the Bank's thinking on the long-run framework for balance sheet operations and then considers how that framework might support countercyclical adjustments of the balance sheet.

The steady-state balance sheet

Two observations have helped to frame the Bank's current thinking on the long-run balance sheet operating framework. First, the stock of assets associated with QE operations should be determined by

91 The June 2018 MPC minutes state "Any reductions in the stock of purchased assets would be conducted over a number of years at a gradual and predictable pace. " and that "As asset sales reduced the quantity of reserves outstanding, the Bank would stand ready to meet banks' demand for additional reserves through regular repo operations. This would result in the level of reserves stabilising as the stock of purchased assets was reduced."

92 For example, Harrison (2012, 2017), Darracq-Paries and Kuehl (2017) and Williams (2013). In the models studied by Harrison (2012, 2017) QE exit strategy is shaped by the nature of the portfolio frictions that give QE traction over long-term interest rates and the fact that these frictions generate welfare costs. Williams (2013) studies a model in which policymakers face Brainard (1967) uncertainty over the efficacy of QE and the short-term policy rate. Under the special assumption that there is additional uncertainty over the effects of QE (in addition to the uncertainty over the effects of the policy rate), it is optimal to delay the use of QE until the policy rate reaches its lower bound and, symmetrically, to unwind asset purchases before raising the policy rate during normalisation. Important simplifications in Williams (2013) are that the uncertainty over the effect of QE is additive (and independent) to the uncertainty over the effect of the policy rate and that uncertainty about the effects of previously implemented QE persists indefinitely. Broadbent (2018) questions the latter assumption.

93 As noted in Section 2, policymakers have long recognised the potential for the effects of QE to be state contingent. There is particular uncertainty about whether the scale of macroeconomic effects at the beginning of QE unwind would be different to QE itself, since the set of observations of such actions is even smaller than the set of asset purchase programmes.

the MPC's judgement on the financial and monetary conditions appropriate to achieve its inflation target. Second, as discussed further below, changes in commercial banks' risk appetite and prudential liquidity regulations imply that the demand for reserves by the commercial banking system is likely to be somewhat higher than observed before the GFC.

These observations suggest that one desirable feature of the operating framework should be to supply the minimum level of reserves required for financial stability purposes independently of any decisions to adjust the stock of assets held for monetary policy purposes.

Hauser (2019) sets out such an approach, building on the Bank's 2018 discussion paper and the subsequent consultation with Sterling Monetary Framework (SMF) participants.[94] In this framework, the Bank would allow reserve holders to determine the reserves they need and would stand ready to lend them. In the limit, this approach would allow the existing stock of QE to be completely unwound (should the MPC deem that appropriate), while still meeting a substantial level of demand for reserves by commercial banks. Hauser (2019) refers to this level of demand as the "preferred minimum range of reserves" (PMRR). Conversely, the approach also permits asset purchases for monetary policy purposes to be undertaken without adverse impacts of an associated increase in reserves on interest rate control.

All else equal, and depending on future MPC decisions on QE unwind, the Bank's future steady state balance sheet would very likely be smaller under this framework than it is today.[95] However, despite the fact that commercial banks would determine the quantity of reserves they need, this approach does not represent a return to the type of scarce reserves regime in operation before the GFC. By standing ready to meet additional demand for reserves via short-term repo-like lending operations secured against HQLA collateral at Bank Rate, the Bank readily supplies reserves to meet the needs of the banking system. In the discussion that follows, these operations are referred to as "Open Market Operations" (OMOs).[96]

A credible commitment to supply reserves against suitable collateral should, all else equal, reduce the demand for reserves in more stable times.[97] Regular OMOs against HQLA collateral should be capable of smoothing over predictable and minor variations in demand. In addition, the Bank's existing liquidity facilities – such as the ILTR and CTRF, which offer reserves against a broad range of eligible collateral – can rapidly inject liquidity into the banking system during stressed market conditions. For the combination of these facilities to reduce demand in stable periods and to be effective when needed, it remains important to protect against the risk of any stigma associated with their use. The Bank's outreach in 2019 suggests that market-wide OMOs (including ILTRs) accessed by multiple banks will reduce this risk.[98]

However, obtaining reserves via repo-like OMOs has a balance sheet cost for commercial banks. So while an abundant supply of reserves will continue to be made available, frictions in the system will act to limit the steady-state quantity of reserves in practice.[99]

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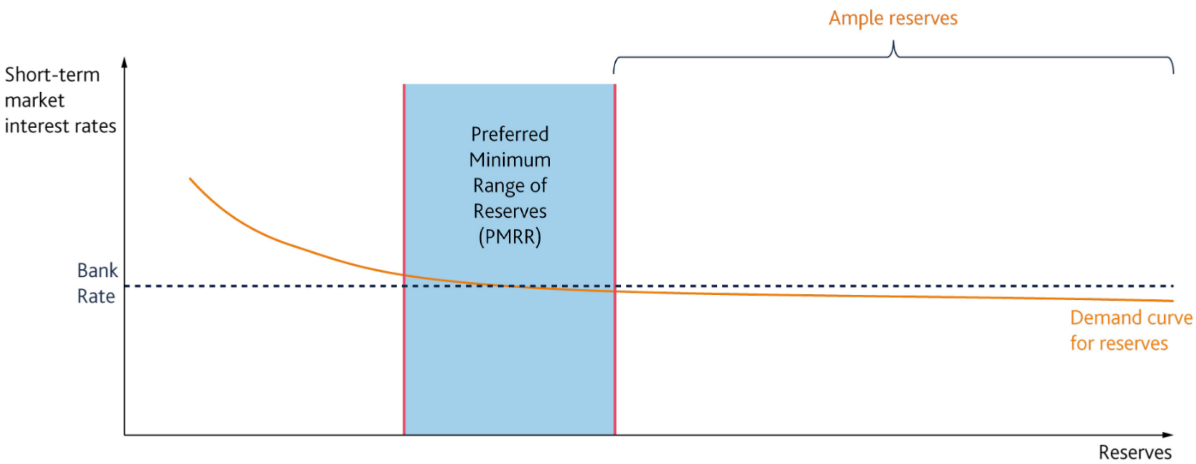
94 "The Bank of England's Future Balance Sheet and Framework for Controlling Interest Rates", 2018.
95 Hauser (2019) provides some illustrative estimates.
96 Note that the definition does not include outright purchases of assets which are often captured in the definition of OMOs in other contexts.
97 Andolfatto and Ihrig (2019) and Quarles (2020) discuss this argument in more detail.
98 'Stigma' refers to the risk that firms are deterred from borrowing from the Bank due to a concern that it may create a perception that their financial position is weak or vulnerable compared to peers. The Winters Review (2012) highlighted stigma as a factor limiting the effectiveness of the Bank's pre-2012 liquidity insurance framework. Since then the Bank has made progress mitigating this concern, as noted in Bank of England Independent Evaluation Office "Evaluation of the Bank of England's Approach to Providing Sterling Liquidity" (2018), having taken a range of actions such as improving the terms, including price, of facilities; reducing the risks of premature disclosure; and providing greater certainty facilities will be available.
99 The demand for reserves depends in part on the framework for supplying them, including the interest rate they earn. There are a variety of alternative approaches to reserve remuneration that have been successfully implemented across different jurisdictions. A full assessment of the implications of these alternatives for the balance sheet framework is beyond the scope of this paper. For the purposes of exposition, the framework set out below follows Hauser (2019) and assumes that reserves continue to be remunerated at Bank Rate.

Additional reserves will only be sought out where they are viewed by the banking system to be the most effective form of liquidity insurance available. This appears to be the case (i) when meeting both expected and unexpected sterling payments during each day; and (ii) when meeting liquidity outflows over short, but multi-day horizons. However the significance of each of these factors is likely to evolve over time – both over the longer term, for example, in response to innovations in payments infrastructure and cyclically, for example, in response to a sudden deterioration in market conditions, as observed in March. Moreover, since the demand for reserves is likely to be influenced by the rate of return that firms can earn on reserves relative to other liquid assets, changes in broader asset prices (and risk premia) may also lead to shifts in the PMRR.

Figure 3 The demand for reserves and the Preferred Minimum Range of Reserves (PMRR)



Alternative approaches to the steady-state operating framework would of course be feasible. For example, rather than reducing the supply of reserves to within the PMRR, the Bank could instead hold a buffer above this level and maintain a more ample supply of reserves. In this alternative framework, money market rates would continue to be influenced primarily by the interest rate paid on reserves rather than the rate at which they can be sourced via OMOs.

Indeed, the Bank's post-QE experience has shown that interest rate control is highly effective under an ample reserves framework. In principle, this framework may be preferable in situations where the demand curve for reserves is sharply upward sloping around the PMRR and autonomous factors can have a large impact on the supply of reserves.[100] The Federal Reserve's recent experience reducing its balance sheet presents such an example. In September 2019, the demand for securities financing increased at a time when autonomous factors sharply reduced the supply of reserves, leading to upward pressure on money market rates.[101]

The PMRR framework is based on the assumption that the demand curve for reserves will have a shallow slope within the PMRR (see **Figure 3**). One factor likely to support this assumption is broad access to OMOs with a large range of eligible institutions expected to be able to source reserves via these operations. Assuming these operations are not stigmatised, this should weaken the impact of unequal distributions in reserves on the marginal demand for reserves. The comparative stability of non-reserve liability balances means that the Bank's balance sheet is less affected by autonomous factors altering the supply of reserves in the UK system. Consequently, changes in reserve supply driven by these factors are relatively small and predictable.

100 Afonso *et al* (2020).
101 Logan (2019).

Another argument in favour of an abundant supply of central bank liabilities is that the central bank can mitigate a threat to financial stability by providing short-term risk-free assets to the market. Greenwood *et al* (2016) argue that in doing so the central bank reduces market-based incentives for private sector intermediaries to create these assets and therefore can crowd out risky private-sector maturity transformation. This would suggest that central banks should maintain larger balance sheets for financial stability reasons.

However, this argument needs to be balanced against the potential adverse effects of a larger central bank balance sheet. Increasing liquidity within the banking system in the form of reserves could come at the expense of the ability of the wider economy to access liquid assets in the form of gilts. It could also prompt changes to the ecosystem in a given market, for example greater concentration and lower efficiency in distributing risk.[102] There may also be circumstances in which QE could exacerbate collateral shortages.[103] More generally, the March 2020 disruption suggests that an ample supply of liabilities in steady state may not necessarily guarantee liquidity in broader financial markets in times of stress.

Figure 3 illustrates the steady-state approach outlined here in relation to the ample reserves alternative.

Cyclical responses to shocks

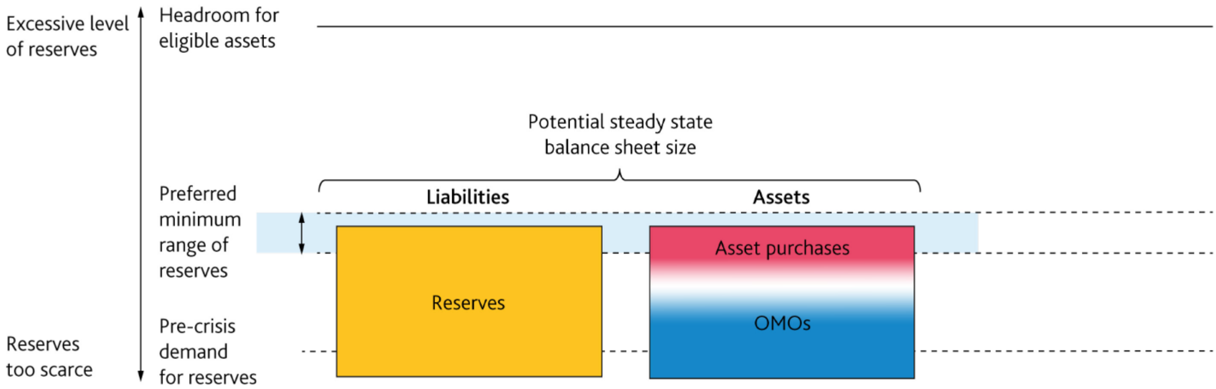
The steady-state framework summarised above can be extended to explore how the balance sheet might adjust in response to two stylised thought experiments. The analysis is structured around simplified representations of the balance sheet.

Figure 4 provides a diagrammatic representation of the steady-state balance sheet outlined in the previous discussion. As discussed previously, the banking system's demand for reserves (the PMRR) is likely to be significantly higher than pre-GFC levels, given liquidity regulations and lower risk appetite. If reserves fall below this level (i.e. banks fail to source sufficient reserves to meet demand) interest rate volatility would increase and (in the limit) raise financial stability concerns regarding the liquidity of the banking system. The lower limit on the size of the balance sheet is determined by the need to meet this level of demand.[104]

Monetary policy operations also influence the asset side of the balance sheet. Limits on the potential to purchase the QE-eligible asset set acts as the upper limit on the size of the balance sheet. As discussed in Section 3.1, in theory, the Bank could purchase the entire stock of gilts and corporate bonds to supply reserves. However, there are likely to be limits to the absolute scale of purchases that are desirable from a financial stability and market functioning perspective. For example, market functioning may deteriorate if a central bank's holdings of securities are particularly large compared to outstanding amounts.[105] As noted previously, beyond a given point, central bank purchases of safe assets may reduce the liquidity resilience of the financial system as these assets are no longer available for non-banks to hold.

102 BIS (2019).
103 See Singh (2013) for example who discusses the impact of QE on collateral dynamics. There are actions that the central bank can take to mitigate these impacts, for example through securities lending programmes which make securities purchased in QE programmes available for short-term purposes.
104 The demand for banknotes is another determinant (abstracted from in what follows for simplicity).
105 BIS (2019).

Figure 4 The size of the steady-state balance sheet in **Figure 3** is determined by the demand for reserves. Reserves are freely supplied at the policy rate against HQLA collateral[106]



The right-hand side of **Figure 5** shows two scenarios in which the balance sheet may need to expand.

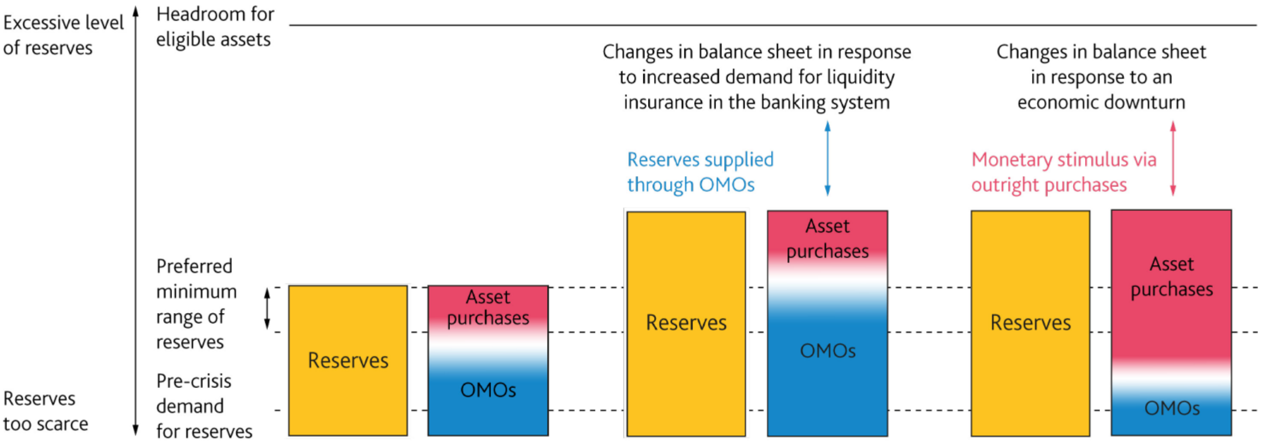
Scenario A is a stylised representation of an increase in demand for reserves by the commercial banking system, prompted by higher demand for liquidity. There could be a range of drivers for the increased demand for liquidity including unexpected shocks which impact market confidence or distress in particular institutions. In these types of situations, risk aversion increases and banks' ability to source reserves via the market is likely to reduce. In this case, the central bank balance sheet plays a crucial role in restoring liquidity and is expanded through increased usage of OMOs and liquidity facilities. A temporary increase in the demand for reserves is quickly reversed out as these operations mature once conditions stabilise.

Scenario B shows a stylised case in which the MPC determines that the economic outlook warrants further asset purchases. A side effect of the QE operation is to increase reserves. Since the QE operation may be persistent, the balance sheet may also expand for some time. During that period, the balance sheet would be in the 'ample reserves' portion of the demand for reserves schedule shown in **Figure 3**. Though the level of reserves would be above the PMRR for some time, the MPC would retain control of the short-term market rates via a floor system, as the excess reserves created would be remunerated at Bank Rate. At the point that the MPC decided that QE unwind was appropriate, allowing bonds to mature without reinvestment and/or the sale of assets would lead to a fall in the supply of reserves and the system would return to steady state.

Of course, these scenarios are highly stylised. However, the balance sheet framework outlined above would likely be robust to many alternatives. For example, in conditions of financial stress a combined scenario is possible in which the actions of both monetary policymakers and the commercial banks lead to an increase in the size of the balance sheet.

106 For simplicity, this diagram excludes particular balance sheet items such e.g. notes outstanding, funding schemes; securities issued; securities held for investment purposes.

Figure 5 Two stylised scenarios of balance sheet adjustment



There may also be situations in which impaired market functioning warrants an intervention by the Bank to backstop key markets where disruption might otherwise have wider economic consequences. For example, the Bank may be required to intervene as Market Maker of Last Resort. The role that the Bank could play in this respect and related considerations are outlined in the August 2020 *Financial Stability Report*.[107] That discussion notes some aspects of these interventions which could be detrimental to financial stability in the future. In particular, it may reduce the incentive on firms to self-insure, thereby giving rise to excessive risk taking.

Many aspects of the Bank's future balance sheet operating framework will be determined over the coming years. However, the framework sketched out in this section may be a useful starting point. It outlines a design for a framework that facilitates countercyclical balance sheet adjustment to support the Bank's financial stability and monetary policy objectives.

107 See Box 7 on page 69 of the August 2020 *Financial Stability Report*.

Conclusion

This paper reviews the role of the central bank balance sheet over the past decade, provides some early observations in light of the Covid crisis response and considers some potential implications for the future.

In the decade since the Global Financial Crisis, policies to address both monetary and financial stability have had material implications for the central bank balance sheet. QE has had the largest balance sheet footprint. While there remains much more to learn, a decade of empirical and theoretical research suggests that QE has successfully lowered long-term interest rates, providing required monetary stimulus.

Globally, the central bank policy response to the Covid crisis has been rapid, wide-ranging and decisive. Now-familiar tools have been recalibrated and newly tailored actions have been introduced, working together to combat an unprecedented shock. Again, the central bank balance sheet has sat at the heart of that response. In the UK, the Bank of England balance sheet is now larger than at any point in its history.

It is too soon to draw firm conclusions on the efficacy of the policy response to Covid and the role of the central bank balance sheet within that. However, some initial – necessarily tentative – observations may provide some helpful guides for future debate. These observations focus on QE, which again played a central role in the crisis response. First, it seems plausible that decisive QE programmes may be particularly effective in times of market dysfunction. Second, a rapid pace of asset purchases may also enhance QE effectiveness during these periods. Taken together, these observations may suggest a particular form of 'state contingency' for the impact of QE. Recognition of this potential for state contingency is not new, but the recent crisis offers a new lens through which to assess its role.

The MPC decides on the overall stock of QE to deliver the required stimulus to meet the inflation target, given prevailing financial conditions. Consistent with the observations above, the decision to 'go big' and to 'go fast' with QE in March 2020 – a period of market turmoil – may well have also avoided an undesirable tightening in those financial conditions. Left unchecked, the market dysfunction at that time could otherwise ultimately have amplified the substantial weakening in the outlook for growth and inflation. Decisive action that was responsive to the degree of market dysfunction was a unifying theme across the global central bank response to the Covid crisis.

While it would be unwise to extrapolate too far, a speculative exploration of this potentially state-contingent impact of QE suggests that judgements on the appropriate policy mix when – and only when – the time comes for policy normalisation may be more nuanced than had been previously thought. As always, any decision on future balance sheet policies would require judgement based on a careful assessment of economic theory, empirical evidence and practical considerations. A more concrete conclusion is that it is highly desirable for the operational framework to support countercyclical movements in the balance sheet, for both monetary policy and financial stability purposes.

A common lesson from both the GFC and the Covid crisis is that policymakers must be prepared to react decisively to the unexpected. For central banks, readiness to use the balance sheet as a policy tool lies at the heart of that preparedness. Many questions remain to be answered in the quest to better understand the effects of balance sheet policies, their optimal deployment and the operating framework that can best support them. These questions will surely set the agenda over the decade ahead, for researchers and policymakers alike.

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Appendix A

The model

The model is based on Harrison (2017), which extends a textbook New Keynesian model (for example, Woodford, 2003; Galí, 2008) to include portfolio frictions. The log-linearised equations are:

$$\pi_t = \kappa x_t + \beta \mathbb{E}_t \pi_{t+1} \tag{1}$$

$$x_t = \mathbb{E}_t x_{t+1} - \sigma\big(i_t - \mathbb{E}_t \pi_{t+1} - \nu q_t - \xi(s_t)(q_t - q_{t-1}) - r^*(s_t)\big) \tag{2}$$

where most variables are expressed as log or percentage point deviations from the steady-state (in particular, inflation is measured as a deviation from target, the policy rate is measured as a deviation from its steady-state value). The exception the quantitative easing (QE) instrument (q) which is expressed as a level.

The Phillips curve (1) is standard and relates inflation (π) to the output gap (x) and expected inflation.

The IS curve (2) relates the output gap to the expected future output gap and monetary conditions. Monetary conditions are measured by the distance between the effective real interest rate and the (exogenous) equilibrium real interest rate, r^*. In contrast to the standard New Keynesian model, the ex ante real interest rate $i_t - \mathbb{E}_t \pi_{t+1}$ is augmented by an additional term representing the effects of quantitative easing, q. In particular, a positive amount of asset purchases $q > 0$ reduces the effective real interest rate by νq. In addition an increase in the stock of assets, $\Delta q > 0$, reduces the effective real interest rate by $\xi(s_t)\Delta q$. The size of the coefficient depends on the exogenous state, s_t.[108]

These assumptions are intended to capture some elements of the particular state contingency explored in Section 2. The fact that in a crisis state the effect of QE depends on the change in the stock of assets captures the notion that the pace of purchases has an important additional effect on the economy. However, there are at least two aspect of the model that may reflect oversimplification. First, the simplified timing structure implies that the term that captures the pace of purchases (Δq) can also be interpreted as a flow effect. Second, the crisis state is modelled as a very large fall in the equilibrium real interest rate, rather than an incipient tightening in financial conditions. To better capture such an effect, a richer framework such as that considered in Sims and Wu (2019) may be more appropriate.

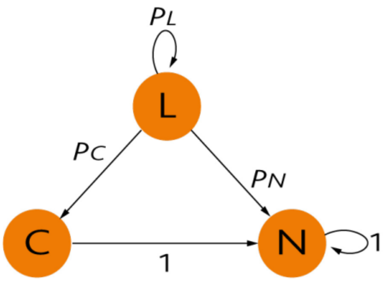
It is assumed that there are three distinct states, defined as follows:

State, s	Description	$\xi(s)$	$r^*(s)$
N	'Normal conditions'	0	0
L	'Low r^*'	0	$r_L^*(< b - \nu\bar{q})$
C	'Crisis'	$\xi(> 0)$	$r_C^*(< b - (\nu + \xi)\bar{q})$

The state s is governed by a Markov process shown in **Figure A1**. This process generalises the one used by Eggertsson and Woodford (2003) by including a 'crisis state'. The 'normal' state is absorbing and the economy is certain to return to normal immediately after a crisis.

108 The portfolio frictions in Harrison (2017) imply that there is an additional term in the expected change in q in the IS curve, (omitted here for simplicity), though the coefficient ξ is not state contingent in that model.

Figure A1 Markov process for r*



The values of r^* corresponding to each state are set with reference to assumed bounds on the policy instruments, as discussed below. Specifically, the policy instruments must satisfy:

$$\begin{aligned} i_t &\geq b \\ q_t &\leq \bar{q} \\ q_t &\geq 0 \end{aligned}$$

where $b < 0$ is the lower bound on the policy rate and $\bar{q} > 0$ is the upper bound on QE.[109]

Optimal policy

The policymaker's loss function is given by:

$$\mathcal{L}_t = \mathbb{E}_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \left(\pi_\tau^2 + \lambda x_\tau^2\right)$$

where $\lambda > 0$ is the relative weight placed on the output gap. An approximation to the utility of agents in the model will typically imply that λ depends on the parameters describing preferences and technology (Woodford, 2003), but here λ is treated as a parameter delegated to the policymaker exogenously.[110] The policymaker is assumed to set policy in a time-consistent manner (so is unable to commit to future policy actions).

Given the structure of the model and the nature of the Markov process, the outcomes and losses in each state are time invariant.[111] In particular, inflation and output in each state are the same regardless of the time period in which that state is reached. The same applies to losses. This implies that:

$$\begin{aligned} \mathcal{L}_L &= \pi_L^2 + \lambda x_L^2 + \beta\left[p_N \mathcal{L}_N + p_C \mathcal{L}_C + p_L \mathcal{L}_L\right] \\ \mathcal{L}_C &= \pi_C^2 + \lambda x_C^2 + \beta \mathcal{L}_N \\ \mathcal{L}_N &= \pi_N^2 + \lambda x_N^2 + \beta \mathcal{L}_N \end{aligned}$$

The first step is to solve for outcomes in state N. Since the deviation of r^* from steady state is zero, it is possible to completely offset the effects of r^* on output and inflation with an unconstrained setting of the instruments.[112] So $\pi_N = x_N = 0$ and so $\mathcal{L}_N = 0$.

109 Note that b is negative because the lower bound is measured relative to the steady state nominal interest rate.

110 In an extension with portfolio frictions (Harrison, 2017), the welfare-based loss function also depends on q because the portfolio frictions induce welfare costs. Such considerations are abstracted from here.

111 Since $\xi = 0$ in state N, there is no endogenous state variable relevant to the decisions in state C. Since entry into state C is only possible from state L, the policy problem in state L accounts for the fact that q is an endogenous state in the event of a transition to state C.

112 Technically, there are an infinite number of feasible unconstrained instrument settings that will deliver this result. If the loss function in state L is assumed to be given by $\mathcal{L}_t = \mathbb{E}_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} (\pi_\tau^2 + \lambda x_\tau^2 + \zeta q_t^2)$ with $\zeta \to 0$, then the unique instrument allocation is $i_N = q_N = 0$.

This means that:

$$\begin{aligned}\mathcal{L}_L =&\ \ \pi_L^2 + \lambda x_L^2 + \beta[p_C\mathcal{L}_C + p_L\mathcal{L}_L] \\ \mathcal{L}_C =&\ \ \pi_C^2 + \lambda x_C^2\end{aligned}$$

Now consider the crisis state. Since it is assumed that $r_C^* < b - (\nu + \xi)\bar{q}$, it is optimal to deploy maximum firepower: $i = b$ and $q = \bar{q}$. This follows because the economy will transition to state N in the following period with certainty, so that the choice of q in state C has no effect on outcomes in state N. The right-hand side of the inequality ($b - (\nu + \xi)\bar{q}$) represents the lowest effective interest rate (including the effects of QE) that can be achieved.[113] Since the equilibrium real rate is lower than this quantity, the policymaker cannot avoid a recessionary outcome.

Outcomes in the crisis state are therefore given by:

$$\begin{aligned}\pi_C =&\ \ \kappa x_C \\ x_C =&\ \ -\sigma(b - \nu\bar{q} - \xi(\bar{q} - q_L) - r_C^*)\end{aligned} \tag{3}$$

The output gap in state C depends on q_L because the economy enters the crisis from state L and the additional power of purchases depends on the change in the stock in state C which is given by $q_C - q_L$. The argument above establishes that $q_C = \bar{q}$.

The loss in the crisis state is therefore given by:

$$\mathcal{L}_C = \ \ (\kappa^2 + \lambda)x_C^2$$

The previous results allow us to solve for state L. Equilibrium outcomes are given by:

$$\begin{aligned}\pi_L =&\ \ \kappa x_L + \beta(p_C\pi_C + p_L\pi_L) \\ x_L =&\ \ p_C x_C + p_L x_L - \sigma(b - (p_C\pi_C + p_L\pi_L) - \nu q_L - r_L^*)\end{aligned}$$

where similar arguments to the analysis of the crisis period imply that $i_L = b$ and this is substituted into the IS curve. Specifically, it is assumed that $r_L^* < b - \nu\bar{q}$, where the right-hand side represents the lowest effective interest rate that can be set by the central bank. Since r_L^* is lower than this rate, the economy will inevitably be in recession. It is therefore optimal to set the loosest stance for the policy rate (since the policy rate has no impact on outcomes in the following period, in any of the states L, C or N). However, the chosen level of QE will affect outcomes in the event that the economy enters state C, as noted above. Hence q_L is an active choice variable.

In state L, previous results establish that the loss function satisfies:

$$\mathcal{L}_L \propto \pi_L^2 + \lambda x_L^2 + \beta p_C \mathcal{L}_C$$

Assuming an interior solution, the first order condition for optimal policy in state L is therefore given by:[114]

113 It is derived by assuming $q_L = 0$, which would provide the maximium policy firepower in state C.

114 The true first order condition will incorporate multipliers on the two constraints on QE ($q_L \geq 0$ and $q_L \leq \bar{q}$). In the event that one constraint binds, those constraints will determine q_L. These multipliers are excluded from the first order condition to aid the exposition.

$$2\pi_L \frac{\partial \pi_L}{\partial q_L} + 2\lambda x_L \frac{\partial x_L}{\partial q_L} + \beta p_C \frac{\partial \mathcal{L}_C}{\partial q_L} = 0$$

Noting that:

$$\frac{\partial \mathcal{L}_C}{\partial q_L} = 2(\kappa^2 + \lambda) x_C \frac{\partial x_C}{\partial q_L}$$

gives

$$\pi_L \frac{\partial \pi_L}{\partial q_L} + \lambda x_L \frac{\partial x_L}{\partial q_L} + \beta p_C (\kappa^2 + \lambda) x_C \frac{\partial x_C}{\partial q_L} = 0 \tag{4}$$

Note that (4) can be written as:

$$\pi_L \frac{\partial \pi_L}{\partial q_L} + \lambda x_L \frac{\partial x_L}{\partial q_L} = -\beta p_C (\kappa^2 + \lambda) x_C \frac{\partial x_C}{\partial q_L} \tag{5}$$

The left hand side of (5) represents the marginal cost of preserving QE headroom: setting q_L below $\bar{q}$ worsens the recession in state L, other things equal. The right hand side represents the foregone marginal benefit of additional headroom in the crisis state.

Further note that, since $\frac{\partial x_C}{\partial q_L} = -\xi\sigma$, the right hand side is given by:

$$-\beta p_C (\kappa^2 + \lambda) x_C \frac{\partial x_C}{\partial q_L} = \beta p_C \xi \sigma (\kappa^2 + \lambda) x_C$$

which is zero if there is no state contingent effect ($\xi = 0$) or the probability of crisis is zero ($p_C = 0$). In either of those cases, which correspond to the conventional assumptions about the transmission mechanism, it is not optimal to preserve policy space, so $q_L = \bar{q}$.[115]

Appendix B shows that the solution for q_L is given by:

$$q_L = -\frac{b - (\nu + \xi)\bar{q} - r_C^*}{\xi\left(1 - \frac{\gamma\nu}{\sigma\xi\delta}\right)} + \frac{\gamma}{\sigma\xi\delta} \frac{r_L^* - b}{1 - \frac{\gamma\nu}{\sigma\xi\delta}}$$

where

115 Since x_L and π_L are both negative and both of their derivatives with respect to q_L are positive, the left-hand side of (5) is negative. The first order condition is satisfied by a non-zero multiplier on the (omitted) Lagrange multiplier on the (binding) upper bound for QE: $q_L \leq \bar{q}$.

$$\gamma = \left[\frac{\kappa^2}{(1-\beta p_L)^2}\left[\nu - \xi p_C\big(1+\sigma\kappa+\beta(1-p_L)\big)\right] + \lambda\left(\nu - \xi p_C\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)\right)\right]\sigma$$

$$\delta = \begin{bmatrix} \frac{\kappa^2}{(1-\beta p_L)^2}\left[\beta + \left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)(1-\beta p_L)\right]\left[\nu - \xi p_C\big(1+\sigma\kappa+\beta(1-p_L)\big)\right] \\ +\left[1+\frac{\sigma\kappa}{1-\beta p_L}\right]\lambda\left(\nu - \xi p_C\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)\right) \\ -\beta\xi(\kappa^2+\lambda)\left[1 - p_L\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)\right]^2 \end{bmatrix} p_C$$

Numerical example

The implications of state contingency are explored using a numerical example. The table below shows the baseline parameter values. As is conventional in models of this type, each time period in the model is assumed to correspond to a quarter.

The top panel is based on Eggertsson and Woodford (2003), with two differences. First, variables are written as 100 times (log) deviations from steady state which affects the scaling of some variables. Second, the inflation target is normalised to zero for simplicity (again this affects scaling).

The middle panel is loosely based on Harrison (2017) , who uses a calibration for ξ that is much higher than ν (though does not account for state dependency) to fit a simple model to US data.

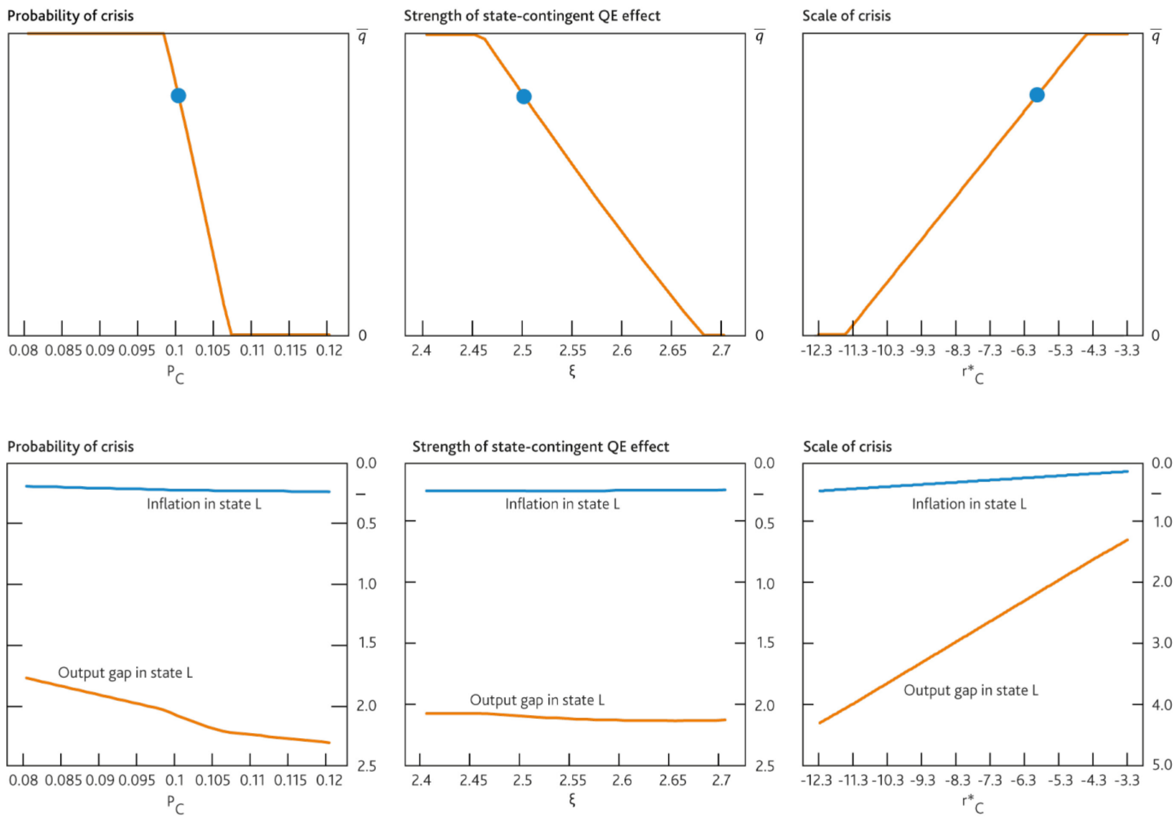
The final panel represents new parameters that are chosen relatively informally. The crisis probability is set equal to the probability of a return to 'normal' (state N). The upper limit for QE is set to 1 (a normalisation). The weight on the output gap in the loss function is set to 0.25 following Carney (2017). Finally, the depth of the crisis (r_C^*) is chosen to deliver an interior solution for q_L: for the baseline parameters, the result is approximately 0.8 (so the policymaker retains 20% of QE policy space in state L).

Baseline parameter values

β	0.99	Household discount factor
σ	0.5	Intertemporal substitution elasticity
κ	0.02	Phillips curve slope
r_L^*	-1.5	r^* in state L
b	-1	Lower bound on policy rate
p_N	0.1	Probability of return to state N (from L)
ν	0.3	'Stock effect' of QE
ξ	2.5	State contingent 'flow effect' of QE
p_C	0.1	Probability of moving to state C
r_C^*	-5.8	r^* in state C
$\bar{q}$	1	Upper bound on QE (normalisation)
λ	0.25	Weight on output gap in loss function

To study the relative importance of these parameters, **Chart A1** plots the effects on equilibrium outcomes as some key assumptions are varied.

Chart A1 Sensitivity of state L outcomes to key parameter values



The top row in **Chart A1** shows solutions for q_L as key assumptions are varied around their baseline values (the baseline solution is shown as a red circle). The bottom row shows the output gap (blue) and inflation (red) in state L. In all cases, the output gap and inflation decrease if policy space is preserved (i.e., as the solution for q_L moves further below $\bar{q}$). Tighter policy in state L depresses output and inflation.

The results show that a higher crisis probability increases the incentive to preserve policy space (q_L falls). A similar result applies to the state contingent strength of asset purchases (ξ). A stronger effect in the crisis state leads to greater policy space preservation. Unsurprisingly, the incentive to preserve policy space increases as the equilibrium real interest rate in the crisis falls. Other things equal, the value of insuring against a crisis increases in the severity of that crisis.

While the sensitivity analysis generates intuitive results, it is worth highlighting that the incentive to insure against a crisis requires that crisis to be extremely large. Given that each time period in the model is one quarter, the crisis must generate a fall in the equilibrium real interest rate of more than 20 percentage points in annualised terms, in order for decisions in state L to be influenced by an insurance motive.

Appendix B: Model solution

From results in the Appendix A, it can be shown that allocations in state L satisfy:

$$
\begin{aligned}
x_L = &\ \frac{\sigma(r_L^* - b)}{1 - p_L\left(1 + \frac{\sigma\kappa}{1 - \beta p_L}\right)} + \frac{\sigma\nu}{1 - p_L\left(1 + \frac{\sigma\kappa}{1 - \beta p_L}\right)} q_L + \frac{p_C\left(1 + \frac{\sigma\kappa}{1 - \beta p_L}\right)}{1 - p_L\left(1 + \frac{\sigma\kappa}{1 - \beta p_L}\right)} x_C \\
\pi_L = &\ \frac{\kappa}{1 - \beta p_L} x_L + \frac{\beta p_C}{1 - \beta p_L} \kappa x_C \\
= &\ \frac{\kappa}{1 - \beta p_L} \frac{\sigma(r_L^* - b)}{1 - p_L\left(1 + \frac{\sigma\kappa}{1 - \beta p_L}\right)} + \frac{\kappa}{1 - \beta p_L} \frac{\sigma\nu}{1 - p_L\left(1 + \frac{\sigma\kappa}{1 - \beta p_L}\right)} q_L \\
&+ \frac{\kappa p_C}{1 - \beta p_L} \frac{\beta + \left(1 + \frac{\sigma\kappa}{1 - \beta p_L}\right)(1 - \beta p_L)}{1 - p_L\left(1 + \frac{\sigma\kappa}{1 - \beta p_L}\right)} x_C
\end{aligned}
$$

Using the solutions for x_L and π_L in (3) gives:

$$
\begin{aligned}
0 = &\ \frac{\partial \pi_L}{\partial q_L} \left[\begin{array}{c} \frac{\kappa}{1 - \beta p_L} \frac{\sigma(r_L^* - b)}{1 - p_L\left(1 + \frac{\sigma\kappa}{1 - \beta p_L}\right)} + \frac{\kappa}{1 - \beta p_L} \frac{\sigma\nu}{1 - p_L\left(1 + \frac{\sigma\kappa}{1 - \beta p_L}\right)} q_L \\ + \frac{\kappa p_C}{1 - \beta p_L} \frac{\beta + \left(1 + \frac{\sigma\kappa}{1 - \beta p_L}\right)(1 - \beta p_L)}{1 - p_L\left(1 + \frac{\sigma\kappa}{1 - \beta p_L}\right)} x_C \end{array} \right] \\
&+ \frac{\partial x_L}{\partial q_L} \lambda \left[\frac{\sigma(r_L^* - b)}{1 - p_L\left(1 + \frac{\sigma\kappa}{1 - \beta p_L}\right)} + \frac{\sigma\nu}{1 - p_L\left(1 + \frac{\sigma\kappa}{1 - \beta p_L}\right)} q_L + \frac{p_C\left(1 + \frac{\sigma\kappa}{1 - \beta p_L}\right)}{1 - p_L\left(1 + \frac{\sigma\kappa}{1 - \beta p_L}\right)} x_C \right] \\
&+ \beta p_C(\kappa^2 + \lambda) \frac{\partial x_C}{\partial q_L} x_C \\
= &\ \left[\frac{\kappa}{1 - \beta p_L} \frac{\partial \pi_L}{\partial q_L} + \lambda \frac{\partial x_L}{\partial q_L} \right] \frac{\sigma(r_L^* - b)}{1 - p_L\left(1 + \frac{\sigma\kappa}{1 - \beta p_L}\right)} \\
&+ \left[\frac{\kappa}{1 - \beta p_L} \frac{\partial \pi_L}{\partial q_L} + \lambda \frac{\partial x_L}{\partial q_L} \right] \frac{\sigma\nu}{1 - p_L\left(1 + \frac{\sigma\kappa}{1 - \beta p_L}\right)} q_L \\
&+ \left[\begin{array}{c} \frac{\kappa}{1 - \beta p_L} \frac{\beta + \left(1 + \frac{\sigma\kappa}{1 - \beta p_L}\right)(1 - \beta p_L)}{1 - p_L\left(1 + \frac{\sigma\kappa}{1 - \beta p_L}\right)} \frac{\partial \pi_L}{\partial q_L} + \frac{1 + \frac{\sigma\kappa}{1 - \beta p_L}}{1 - p_L\left(1 + \frac{\sigma\kappa}{1 - \beta p_L}\right)} \lambda \frac{\partial x_L}{\partial q_L} \\ + \beta(\kappa^2 + \lambda) \frac{\partial x_C}{\partial q_L} \end{array} \right] p_C x_C
\end{aligned}
$$

Previous results reveal that:

$$
\begin{aligned}
\frac{\partial x_C}{\partial q_L} &= -\xi\sigma \\
\frac{\partial x_L}{\partial q_L} &= \frac{\sigma\nu}{1-p_L\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)}+\frac{p_C\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)}{1-p_L\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)}\frac{\partial x_C}{\partial q_L} \\
&= \frac{\sigma\left(\nu-\xi p_C\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)\right)}{1-p_L\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)} \\
\frac{\partial \pi_L}{\partial q_L} &= \frac{\kappa}{1-\beta p_L}\frac{\partial x_L}{\partial q_L}+\frac{\beta p_C}{1-\beta p_L}\kappa\frac{\partial x_C}{\partial q_L} \\
&= \frac{\sigma\kappa}{1-\beta p_L}\frac{\nu-\xi p_C\big(1+\sigma\kappa+\beta(1-p_L)\big)}{1-p_L\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)}
\end{aligned}
$$

Using the solutions for x_L and π_L in (3) gives:

$$
\begin{aligned}
0 =\ & \frac{\partial \pi_L}{\partial q_L}\left[\begin{array}{c}\frac{\kappa}{1-\beta p_L}\frac{\sigma(r_L^*-b)}{1-p_L\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)}+\frac{\kappa}{1-\beta p_L}\frac{\sigma\nu}{1-p_L\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)}q_L \\ +\frac{\kappa p_C}{1-\beta p_L}\frac{\beta+\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)(1-\beta p_L)}{1-p_L\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)}x_C\end{array}\right] \\
&+\frac{\partial x_L}{\partial q_L}\lambda\left[\frac{\sigma(r_L^*-b)}{1-p_L\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)}+\frac{\sigma\nu}{1-p_L\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)}q_L+\frac{p_C\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)}{1-p_L\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)}x_C\right] \\
&+\beta p_C(\kappa^2+\lambda)\frac{\partial x_C}{\partial q_L}x_C \\
=\ & \left[\frac{\kappa}{1-\beta p_L}\frac{\partial \pi_L}{\partial q_L}+\lambda\frac{\partial x_L}{\partial q_L}\right]\frac{\sigma(r_L^*-b)}{1-p_L\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)} \\
&+\left[\frac{\kappa}{1-\beta p_L}\frac{\partial \pi_L}{\partial q_L}+\lambda\frac{\partial x_L}{\partial q_L}\right]\frac{\sigma\nu}{1-p_L\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)}q_L \\
&+\left[\begin{array}{c}\frac{\kappa}{1-\beta p_L}\frac{\beta+\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)(1-\beta p_L)}{1-p_L\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)}\frac{\partial \pi_L}{\partial q_L}+\frac{1+\frac{\sigma\kappa}{1-\beta p_L}}{1-p_L\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)}\lambda\frac{\partial x_L}{\partial q_L} \\ +\beta(\kappa^2+\lambda)\frac{\partial x_C}{\partial q_L}\end{array}\right]p_C x_C
\end{aligned}
$$

Using these results in the first order condition gives:

$$
\begin{aligned}
0 = \;& \frac{\frac{\kappa^2}{(1-\beta p_L)^2}\left[\nu - \xi p_C\big(1+\sigma\kappa+\beta(1-p_L)\big)\right] + \lambda\left(\nu - \xi p_C\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)\right)}{\left[1-p_L\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)\right]^2}\sigma^2(r_L^* - b) \\
&+ \frac{\frac{\kappa^2}{(1-\beta p_L)^2}\left[\nu - \xi p_C\big(1+\sigma\kappa+\beta(1-p_L)\big)\right] + \lambda\left(\nu - \xi p_C\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)\right)}{\left[1-p_L\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)\right]^2}\sigma^2\nu q_L \\
&+ \left[\begin{array}{l} \frac{\kappa^2}{(1-\beta p_L)^2}\frac{\beta+\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)(1-\beta p_L)}{\left[1-p_L\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)\right]^2}\left[\nu - \xi p_C\big(1+\sigma\kappa+\beta(1-p_L)\big)\right] \\ + \frac{1+\frac{\sigma\kappa}{1-\beta p_L}}{\left[1-p_L\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)\right]^2}\lambda\left(\nu - \xi p_C\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)\right) - \beta\xi(\kappa^2+\lambda) \end{array}\right]\sigma p_C x_C \\
= \;& \left[\frac{\kappa^2}{(1-\beta p_L)^2}\left[\nu - \xi p_C\big(1+\sigma\kappa+\beta(1-p_L)\big)\right] + \lambda\left(\nu - \xi p_C\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)\right)\right]\sigma(r_L^* - b) \\
&+ \left[\frac{\kappa^2}{(1-\beta p_L)^2}\left[\nu - \xi p_C\big(1+\sigma\kappa+\beta(1-p_L)\big)\right] + \lambda\left(\nu - \xi p_C\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)\right)\right]\sigma\nu q_L \\
&+ \left[\begin{array}{l} \frac{\kappa^2}{(1-\beta p_L)^2}\left[\beta+\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)(1-\beta p_L)\right]\left[\nu - \xi p_C\big(1+\sigma\kappa+\beta(1-p_L)\big)\right] \\ + \left[1+\frac{\sigma\kappa}{1-\beta p_L}\right]\lambda\left(\nu - \xi p_C\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)\right) - \beta\xi(\kappa^2+\lambda)\left[1-p_L\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)\right]^2 \end{array}\right] p_C x_C \\
= \;& \gamma(r_L^* - b) + \gamma\nu q_L + \delta x_C
\end{aligned}
$$

where

$$
\begin{aligned}
\gamma = \;& \left[\frac{\kappa^2}{(1-\beta p_L)^2}\left[\nu - \xi p_C\big(1+\sigma\kappa+\beta(1-p_L)\big)\right] + \lambda\left(\nu - \xi p_C\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)\right)\right]\sigma \\
\delta = \;& \left[\begin{array}{l} \frac{\kappa^2}{(1-\beta p_L)^2}\left[\beta+\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)(1-\beta p_L)\right]\left[\nu - \xi p_C\big(1+\sigma\kappa+\beta(1-p_L)\big)\right] \\ + \left[1+\frac{\sigma\kappa}{1-\beta p_L}\right]\lambda\left(\nu - \xi p_C\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)\right) - \beta\xi(\kappa^2+\lambda)\left[1-p_L\left(1+\frac{\sigma\kappa}{1-\beta p_L}\right)\right]^2 \end{array}\right] p_C
\end{aligned}
$$

This implies that

$$x_C = -\gamma\delta^{-1}(r_L^* - b) - \gamma\nu\delta^{-1}q_L$$

The solution for x_C, (3), implies that:

$$q_L = -\xi^{-1}(b - (\nu+\xi)\bar{q} - r_C^*) - (\sigma\xi)^{-1}x_C$$

Combining the previous two equations implies that:

$$\begin{aligned} q_L = &\quad -\xi^{-1}(b-(\nu+\xi)\bar{q}-r_C^*) - (\sigma\xi)^{-1}[-\gamma\delta^{-1}(r_L^*-b) - \gamma\nu\delta^{-1}q_L] \\ = &\quad -\xi^{-1}(b-(\nu+\xi)\bar{q}-r_C^*) + (\sigma\xi\delta)^{-1}\gamma(r_L^*-b) + (\sigma\xi\delta)^{-1}\gamma\nu q_L \end{aligned}$$

so that

$$q_L = -\frac{b-(\nu+\xi)\bar{q}-r_C^*}{\xi\left(1-\frac{\gamma\nu}{\sigma\xi\delta}\right)} + \frac{\gamma}{\sigma\xi\delta}\frac{r_L^*-b}{1-\frac{\gamma\nu}{\sigma\xi\delta}}$$