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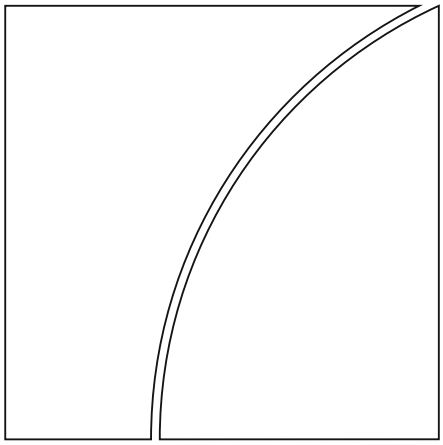

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by Henning Hesse, Boris Hofmann, James Weber

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The Macroeconomic Effects of Asset Purchases Revisited[#]

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Abstract

This paper revisits the macroeconomic effects of the large-scale asset purchase programmes launched by the Federal Reserve and the Bank of England from 2008. Using a Bayesian VAR, we investigate the macroeconomic impact of shocks to asset purchase announcements and assess changes in their effectiveness based on subsample analysis. The results suggest that the early asset purchase programmes had significant positive macroeconomic effects, while those of the subsequent ones were weaker and in part not significantly different from zero. The reduced effectiveness seems to reflect in part better anticipation of asset purchase programmes over time, since we find significant positive macroeconomic effects when we consider shocks to survey expectations of the Federal Reserve's last asset purchase programme. Finally, in all estimations we find a significant and persistent positive impact of asset purchase shocks on stock prices.

Keywords: unconventional monetary policy, asset purchases, monetary transmission.

JEL classification: E50, E51, E52.

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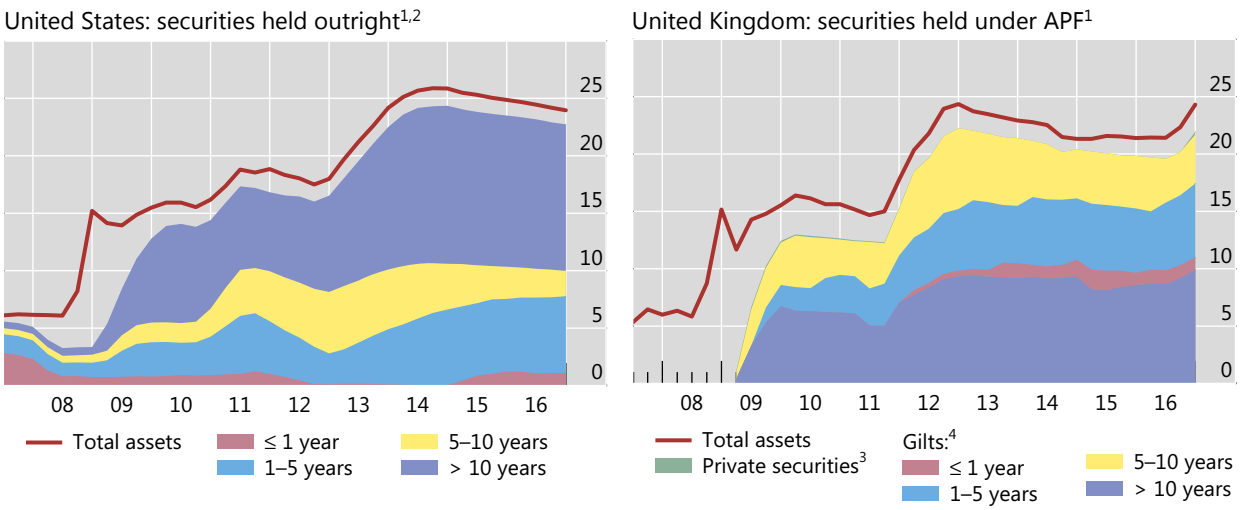
1. Introduction

In the wake of the Great Financial Crisis (GFC), all major advanced economy central banks embarked on large-scale asset purchase programmes to provide additional monetary stimulus. In particular, the Federal Reserve and the Bank of England both launched such programmes shortly after the outbreak of the crisis and implemented further purchases during the following years of recovery, raising their outright securities holdings above 20% of national GDP (Figure 1). There is widespread agreement that the stimulus provided by these measures was crucial in halting the crisis and preventing a deeper, more protracted recession. This notion is supported by formal empirical evidence suggesting that the measures have eased monetary conditions, e.g. by lowering interbank rates, bond yields and credit risk spreads, and have also boosted the economy (see Borio and Zabai (2016) for an overview and the references therein).

Figure 1: Central bank balance sheets

As a percentage of GDP



[1] By remaining maturity. [2] Face value. [3] Includes commercial paper and corporate bonds. [4] Proceeds.

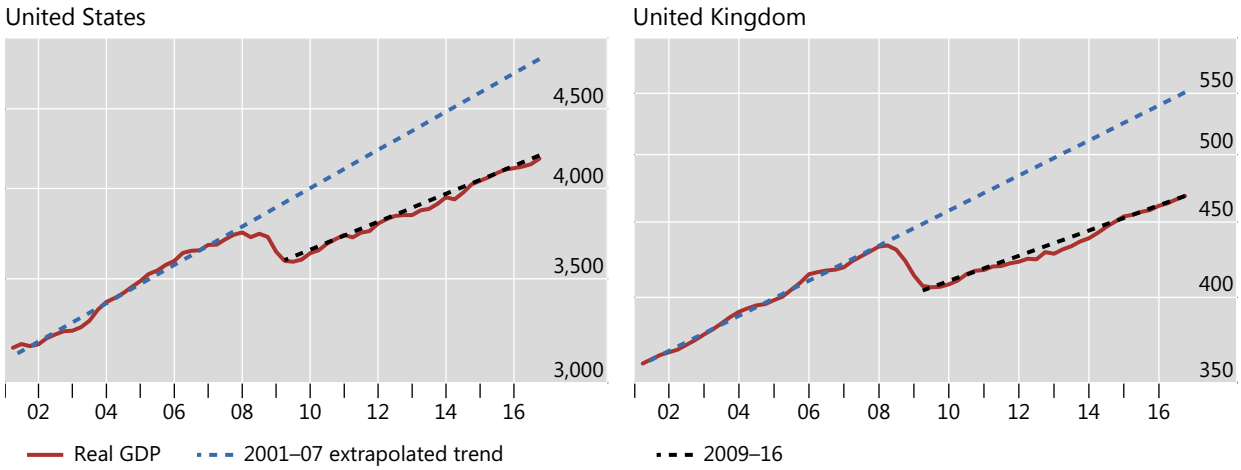
Source: National data.

The lacklustre recovery from the GFC has, however, raised questions about the potentially reduced effectiveness of the extraordinary measures over time. In spite of the massive stimulus, output has not returned to its pre-recession path in either the United States or the United Kingdom, evolving instead along a lower and flatter trajectory (Figure 2). Against this backdrop, this paper revisits the macroeconomic effects of large-scale central bank asset purchases in these two countries, focusing on the question whether the effects have diminished over time.[1]

[1] We do not consider the euro area and Japan, as these two economies have gone through different phases in terms of crisis, recovery and asset purchases since 2008. In response to the euro area sovereign debt crisis and its aftermath, the ECB launched several balance sheet policy measures, including targeted and large-scale asset purchases. The Bank

Figure 2: Real GDP pre- and post-crisis

In billions of local currency units



Seasonally adjusted.

Sources: national data; BIS calculations.

From a conceptual point of view, a number of considerations suggest that the effectiveness of asset purchases could diminish when the economy moves from crisis/recession to recovery mode. The financial market impact of a given amount of asset purchases may fall as financial market conditions normalise and low interest rates persist. The portfolio-rebalancing channel (i.e. the effect of bond purchases on bond prices and yields working through the reduction in the net supply of the purchased bonds) may be stronger under stressed financial market conditions, and consequently weaker once conditions normalise.[2] Similarly, the impact through confidence channels (i.e. the more general effect of purchases on consumer and investor confidence) is probably larger when uncertainty is high and may fade when it normalises. Also the signalling channel (i.e. the effect of asset purchases on bond yields working through its impact on the expected path of future short rates) may weaken when short-term rates have been at very low levels for an extended period of time.

At the same time, the macroeconomic effect of a given financial market impact of asset purchases may fall in the recovery from acute financial stress when low interest rates have prevailed for an extended period of time, as reviewed in detail in Borio and Hofmann (2017). Monetary policy transmission may be weakened because of macro-financial "headwinds" that blow in the recovery from a financial crisis. Specifically, debt overhang, an impaired financial sector and heightened uncertainty may sap the effectiveness of monetary stimulus. At the same time, persistent low

of Japan aggressively expanded asset purchases in 2013 through quantitative and qualitative easing (QQE) in order to overcome Japan's deflation that persisted over decades. Thus, while for the United States and the United Kingdom there is a relatively clear distinction between crisis and recovery since 2008, and the asset purchase programmes launched during the former and programmes launched during the latter phase, the same easy distinction cannot be made for the euro area and Japan.

[2] Curdia and Woodford (2011) suggest that targeted asset purchases can lower credit risk spreads when financial market conditions are distressed, implying in reverse that there is no case for such a policy when market conditions return to normal. Also in preferred-habitat models (Vayanos and Vila (2009), Greenwood and Vayanos (2010, 2012)), i.e. models where some investors have a preference for certain bond maturities, it can be shown that the impact of bond supply on bond yields becomes weaker when investors' risk aversion is lower (Strohsal (2013)). By implication, central bank large-scale asset purchases reducing net bond supply would have larger negative effects on bond yields when risk aversion is high compared to situations when it is low.

interest rates may erode transmission in a number of ways. These include adverse effects of low rates on bank profitability and ultimately on credit supply as net interest margins become compressed; a potential increase in savings if low interest rates render agents' envisaged lifetime savings insufficient to ensure an adequate standard of living after retirement; resource misallocation driven by low interest rates, e.g. through zombie lending by banks; and negative confidence effects, as persistent low rates could be perceived as a negative signal about economic prospects.

Finally, as successive rounds of asset purchase programmes were launched, they may over time have become better anticipated by markets and economic agents. As a consequence, measuring the financial market and macroeconomic effects of asset purchases may have become more difficult. If the effects of asset purchases are identified based on the timing of their announcement, as is widely done in the literature, a better anticipation of the programmes might reduce measured effectiveness as they may have been at least partly priced in already before the actual announcement.

Evidence for the changing effectiveness of asset purchases has previously been limited. While a number of studies report a reduced impact on long-term interest rates of the consecutive programmes (see Borio and Zabai (2016) and the references therein), very few studies have assessed changes in the macroeconomic effects. One obvious reason is the small sample size available to test this hypothesis since asset purchase programmes in the United States and the United Kingdom were initiated only in 2008/2009. This poses a challenge to any assessment of the macroeconomic effects of the programmes, to say nothing of changes in the effects over time.3 That said, with more than eight years of data now available, assessing whether the effects have changed over time should be increasingly possible, although the results must obviously be taken with a pinch of salt.

The scant evidence does not paint a clear picture. Panizza and Wyplosz (2016) explore the decreasing effectiveness hypothesis for the core advanced economies that implemented large-scale asset purchases (United States, euro area, Japan and United Kingdom) based on subsample analysis. They come to inconclusive results. For some empirical specifications they find decreasing effectiveness, for others not. Haldane et al (2016) consider differences in the impact of asset purchase shocks depending on the state of financial market stress. For the United States and the United Kingdom, they find that asset purchase shocks have a significant effect when financial market stress is high (i.e. between 2008 and 2010), but that the effects are generally smaller when it is low (i.e. post-2010).

This paper revisits the effectiveness of asset purchases in the United States and the United Kingdom following and extending the analysis of previous papers. We follow the empirical approach of Weale and Wieladek (2016) to analyse the macroeconomic effects of asset purchase shocks by estimating small-scale VARs, using a cumulative asset purchase announcement series as the policy instrument. Changes over time in the effectiveness of asset purchases are assessed based on subsample estimations. Specifically, we compare the dynamic effects of the early programmes, over the period 2008 to mid-2011, with those of the later programmes launched after mid-2011. This sample split is similar to the approach taken by Panizza and Wyplosz (2016) and Haldane et al (2016). We also perform the analysis looking at term spread shocks following Baumeister and Benati (2013) and Kapetanios et al (2012), as well as shocks to expected asset purchases from the Federal Reserve Bank of New York's primary dealer survey. These exercises serve to assess the relevance of better anticipation of later asset purchase programmes compared to earlier ones, which could artificially reduce their estimated effectiveness.

[3] For a review of the empirical studies on the macroeconomic effects of central bank asset purchases, see also Borio and Zabai (2016).

Besides the question of a changing macroeconomic impact, a secondary focus of our analysis is the impact of asset purchases on the stock market relative to that on the macroeconomy. The empirical set-up allows us to assess this point, as equity prices are part of the empirical model used to assess the macroeconomic effects of asset purchases. The question is pertinent as some observers have raised concerns that, even if asset purchases had exerted positive macroeconomic effects, they may have contributed to inflating stock prices, raising the risks of renewed financial turmoil down the road. Indeed, from a conceptual point of view, the impact of asset purchases on risky assets such as stocks may have strengthened through a number of channels, potentially counteracting or even offsetting the above-mentioned weakening effects. Persistent low interest rates may foster more aggressive risk-taking by investors, which over time could strengthen the impact of asset purchases on risky assets, such as stock prices. Moreover, standard dividend discount models suggest that a change in real rates has a larger effect on stock prices when the level of real interest rates is low.

The results of the baseline analysis suggest that, for both the United States and the United Kingdom, the effectiveness of asset purchases has fallen. The analysis shows that, while an asset purchase shock under the early purchase programmes had a significant positive impact on real GDP and the price level both in the United States and the United Kingdom, the effects of the same-sized shock were much smaller and in part not statistically different from zero for subsequent programmes. Also, for a term spread shock, we find smaller effects over time. However, the macroeconomic effects of asset purchase shocks during the last large-scale asset purchase programme in the United States are significantly positive when we use survey expectations of the size of the purchases. This suggests that better anticipation of asset purchase programmes over time may in part explain the reduced effectiveness of later programmes that was established in the preceding analysis.

We further find that the impact of asset purchase shocks on stock prices was considerably larger than the impact on output and prices. Moreover, while some specifications yield macroeconomic effects that declined over time and even became insignificantly different from zero, the estimated impact on stock prices always remained persistently positive and statistically significant.

The remainder of the paper is organised as follows. Section 2 describes the empirical approach and the data used in the analysis. Section 3 presents the baseline results. Section 4 assesses the macroeconomic impact of asset purchases based on term premium shocks. Section 5 considers expected asset purchases in the United States from the primary dealer survey. Section 6 concludes.

2. Empirical set-up

VAR model and data

We follow Weale and Wieladek (2016) and analyse the macroeconomic effects of asset purchases in the United States and the United Kingdom based on a monthly VAR.[4] The VAR takes the form:

$$Y_t = \alpha + A(L)Y_{t-1} + B\varepsilon_t$$

where Y_t is a vector of endogenous variables, α is a vector of constants, $A(L)$ a matrix polynomial in the lag operator L, and B is the contemporaneous impact matrix of the mutually uncorrelated shocks ε_t. The endogenous variables comprise the logarithm of monthly (seasonally adjusted) real

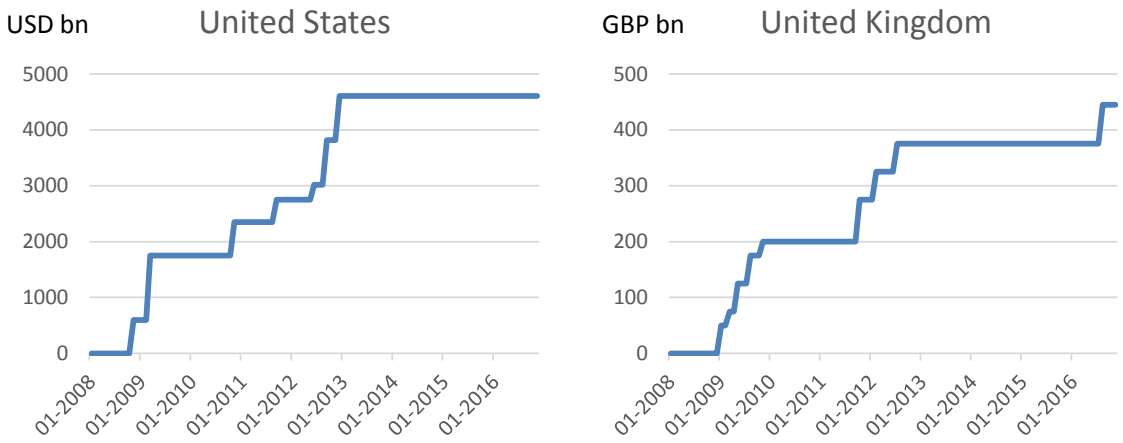
[4] The exposition in this section follows Boeckx et al (2017) who use a similar empirical approach to analyse the effectiveness of the ECB's balance sheet policies.

gross domestic product (GDP), the logarithm of the (seasonally adjusted) consumer price index (CPI), the cumulative sum of asset purchase announcements, the yield on long-term government bonds, and the logarithm of the real stock price index (deflated with the CPI).

For the United States, we use the CPI, the 10-year government bond yield and the S&P 500 from the Federal Reserve Economic Data (FRED) database, and monthly real GDP from Macroeconomic Advisors. The CPI, the 10-year government bond yield and the FTSE-100 stock price index for the United Kingdom are from the Office for National Statistics (ONS), the monthly real GDP series is from the National Institute for Economic and Social Research (NIESR).

We obtain the cumulative sum of asset purchase announcements in the United States by adding up the Federal Reserve's announced purchases of Treasuries, mortgage-backed securities (MBS) and agency debt under the three large-scale asset purchase programmes (LSAP1, LSAP2 and LSAP3) and under the maturity extension programme (MEP). For the United Kingdom, we cumulate the Bank of England's asset purchase announcements under the Asset Purchase Facility (APF).5 Annex Table A1 provides a chronology of the two central banks' asset purchase announcements and Figure 3 shows the cumulative asset purchase announcement series.

Figure 3: Cumulative asset purchase announcements



A complication in the construction of the asset purchase announcement series for the United States is the open-ended nature of the Federal Reserve's third large-scale asset purchase programme (LSAP3). In September and December 2012, the Federal Reserve announced the monthly pace of the MBS and Treasury purchases under this programme, but not the precise time horizon over which they would take place, so that the overall size of the programme was unclear. We quantify the implied size of LSAP3 by assuming that the total size of the purchases was correctly anticipated.6 In other words, we add the total realised purchases of MBS and Treasuries at the time

5 Analysing the impact of asset purchases based on shocks to the cumulative sum of all asset purchase announcements over time involves the assumption that the full impact of an asset purchase programme unfolds immediately upon its announcement, i.e. that financial markets immediately and fully price in the effects. This means that the effects are assumed to work through a stock effect, i.e. the impact from the expected reduction in bond supply brought about by the asset purchase programme, rather than a flow effect, i.e. the impact on financial markets of the actual bond purchases. This assumption is in line with the evidence of large stock effects and small flow effects of large-scale asset purchase programmes (see e.g. D'Amico and King (2013)).

6 Weale and Wieladek (2016) and Panizza and Wyplosz (2016) set the size of LSAP3 to zero on the grounds that it is difficult to quantify ex ante. This solution is, however, not very appealing in our view, since the expected size of the

of the respective announcements. In Section 5 we also consider primary dealer expectations of LSAP3 purchases, which is however only possible beginning in mid-2012. In the analysis, we normalise both asset purchases announcement series by the respective 2009Q1 value of GDP in order to obtain measures of asset purchase announcements that are quantitatively comparable across the two countries.

The VAR is estimated on monthly data spanning the period over which asset purchase programmes were operated, which is November 2008 to October 2014 for the United States and January 2009 to November 2016 for the United Kingdom.7 In the latter case, the sample end point is determined by data availability as, at the time of writing, the Bank of England was still making asset purchases. Finally, the lag order of the VAR is set to two based on indications of standard lag order selection tests and in line with the lag order used by Weale and Wieladek (2016).

Identification of asset purchase shocks

For the identification of the asset purchase announcement shock, we use a combination of zero and sign restrictions akin to the scheme used by Gambacorta et al (2014). We assume that an asset purchase shock has no immediate impact on output and prices, reflecting the notion that these variables are sticky in the short run. This is a standard identification assumption in the monetary transmission literature (see e.g. Christiano et al (1996, 1999)) and offers a convenient way to disentangle the asset purchase shock from aggregate demand and supply shocks. We further assume, following Weale and Wieladek (2016), that an expansionary asset purchase shock increases announced asset purchases, increases real stock prices and reduces long-term bond yields.[8] In other words, we hardwire some effectiveness of transmission through financial markets into the system, while we leave open the effects on the macroeconomy.[9]

The identifying restrictions are summarised in Table 1. Following Weale and Wieladek (2016), we impose the sign restrictions on the long-term yield and on stock prices upon impact and the following month, while the sign restrictions for the asset purchase announcement series are imposed on impact and the following five months. The estimation and inference use the Bayesian approach developed in Uhlig (2005) and Peersman (2005), with the prior and posterior distributions of the reduced form VAR belonging to the Normal-Wishart family. More precisely, impulse responses are constructed by taking a joint draw from the unrestricted Normal-Wishart posterior

programme when it was announced was certainly not zero. Running our models with LSAP3 calibrated in this manner yields very wide error bands for the impulses responses. By contrast, alternative informed guesses of the implied size of LSAP3, such as the one considered by Weale and Wieladek (2016) in their robustness checks, where the duration of the programme is calibrated based on communications of the Federal Reserve with respect to the prospective timing of policy rate lift-off, yield results very similar those obtained under our baseline assumption. The results for alternative calibrations of the size of LSAP3 are available upon request.

7 The results are robust to extending the sample period for the United States to end 2016, as Panizza and Wyplosz (2016) do.

8 This restriction is similar to the one used in Gambacorta et al (2014) who impose the restriction that an expansionary unconventional monetary policy shock increases the size of the central bank balance sheet and lowers stock market volatility.

9 Our identification can be seen as a blend of identification schemes I (pure timing restrictions) and II (pure sign restrictions) in Weale and Wieladek (2016). Panizza and Wyplosz (2016) adopted the pure sign restrictions approach. However, this approach requires also identifying the aggregate demand and the aggregate supply shock with appropriate sign restrictions, which is not always innocuous. For instance, Weale and Wieladek (2016) identify the aggregate supply shock by imposing the restrictions that it has a negative effect on prices and a positive impact on output, equity prices and bond yields. However, it is not clear a priori whether the latter restriction is appropriate given the assumed negative effect on prices, which could also lower inflation expectations. Our combination of zero and sign restrictions offers, in our view, a cleaner and simpler way to disentangle asset purchase shocks from aggregate demand and supply shocks.

for the VAR parameters as well as a random possible decomposition B of the variance-covariance matrix. We keep the draw if the VAR is stationary and the impulse response functions satisfy the imposed restrictions in Table 1. Otherwise, we reject the draw by giving it a zero prior weight. A total of 10,000 successful Monte Carlo draws from the posterior are used to produce the median impulse responses and 84th and 16th percentile error bands.

Table 1: Identifying restrictions for the asset purchase announcement shock

Output	Prices	Stock prices	Bond yields	Asset purchase announcement
0	0	≥0	≤0	≥0

Note: Zero restrictions on output and prices are imposed on impact. Sign restrictions are imposed on periods 0 and 1 for the bond yields and stock prices and for periods 0 to 5 for the asset purchase announcement series.

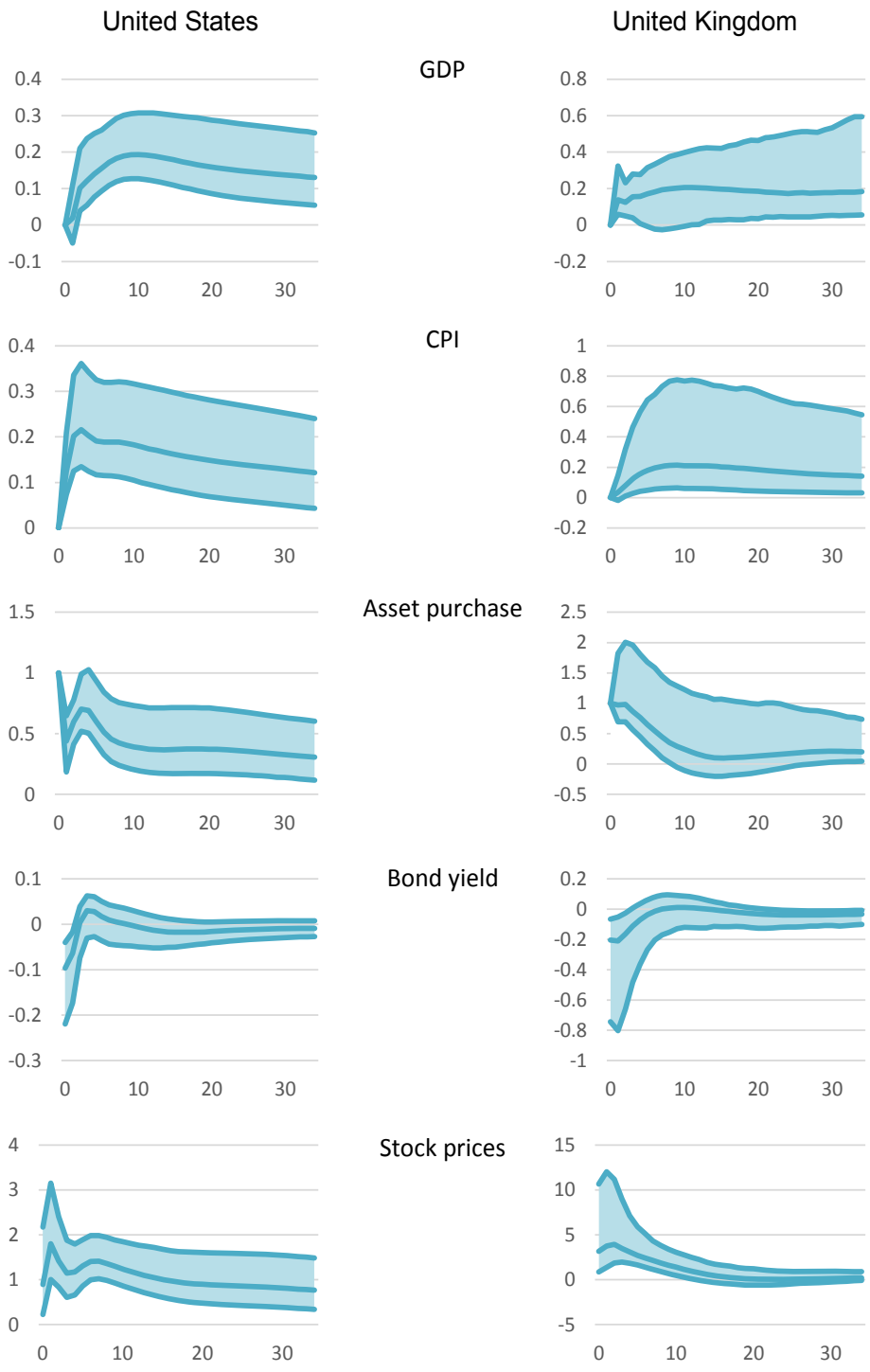
3. Results

Full sample results

We first assess the effects of asset purchase shocks over the full sample period over which asset purchase programmes were operated, i.e. over the period November 2008 until October 2014 for the United States and January 2009 until November 2016 for the United Kingdom. In order to enhance comparability of the results across the two countries, we normalise the size of the asset purchase announcement shock to 1% of 2009Q1 GDP, following Weale and Wieladek (2016).

The impulse responses, which are shown in Figure 4, are broadly in line with those reported in Weale and Wieladek (2016). In both the United States and the United Kingdom, we obtain significant and persistent positive effects on real GDP and the CPI. Quantitatively, the peak impacts on the macroeconomic variables are very similar in the two economies, with a maximum increase of both real GDP and the CPI of around 0.2% after an asset purchase announcement shock (that is equal to 1% of the nominal GDP in 2009Q1). Bond yields display a short-lived fall of up to 10 basis points in the United States and up to 20 basis points in the United Kingdom. Stock prices, in turn, increase persistently by up to 2% in the United States and 4% in the United Kingdom. This means that the peak impact of asset purchase announcements on real stock prices is 10 times larger in the United States and 20 times larger in the United Kingdom than the maximum effect on real output. The impact of asset purchase announcements on real stock prices relative to real GDP is comparable to that obtained for conventional monetary policy shocks (see e.g. Bjørnland and Leitemo (2009), Eickmeier and Hofmann (2013)).

Figure 4: Impulse responses to an asset purchase announcement shock (full sample)



Median responses with 16th and 84th percentiles error bands. The asset purchase announcement shock is normalised to the size of 1% of annualized Q1 2009 GDP. The sample period is 11/2008 to 10/2014 for the United States and 01/2009 to 11/2016 for the United Kingdom.

Subsample results

In order to evaluate changes in the effect of the asset purchase announcements, we split the sample into two and perform the analysis for each of the subsamples separately. The first subsample spans

the period from November 2008 to June 2011 for the United States and from January 2009 to June 2011 for the United Kingdom. This period includes the initial phase of the crisis and its immediate aftermath, covering the early asset purchase programmes launched by the two central banks. The second subsample spans the period from July 2011 to October 2014 for the United States and from July 2011 to November 2016 for the United Kingdom, covering the subsequent asset purchase programmes launched during the recovery from the GFC (see Annex Table A1).[10]

Figure 5 shows the impulse responses for the two subsample periods. The IRFs from the first sample period are in red, those from the second sample period are in blue. In order to eliminate the effect of a change in the size of the asset purchase announcement innovation on the impulse responses, we again rescale the size of the shock to be the same in both sample periods, i.e. to 1% of the 2009Q1 nominal GDP.

The results indicate a weakening of the macroeconomic effects of asset purchase announcement shocks over time. We find significant positive effects on real GDP and CPI for the first subsample period. In the second period, the estimated effects are smaller and often not significantly different from zero. In particular, the dynamic effects of the shock on real GDP are insignificant in both countries. The CPI still responds in a marginally significant positive way. However, the magnitude of the response is far smaller, and in the case of the United Kingdom also less persistent.

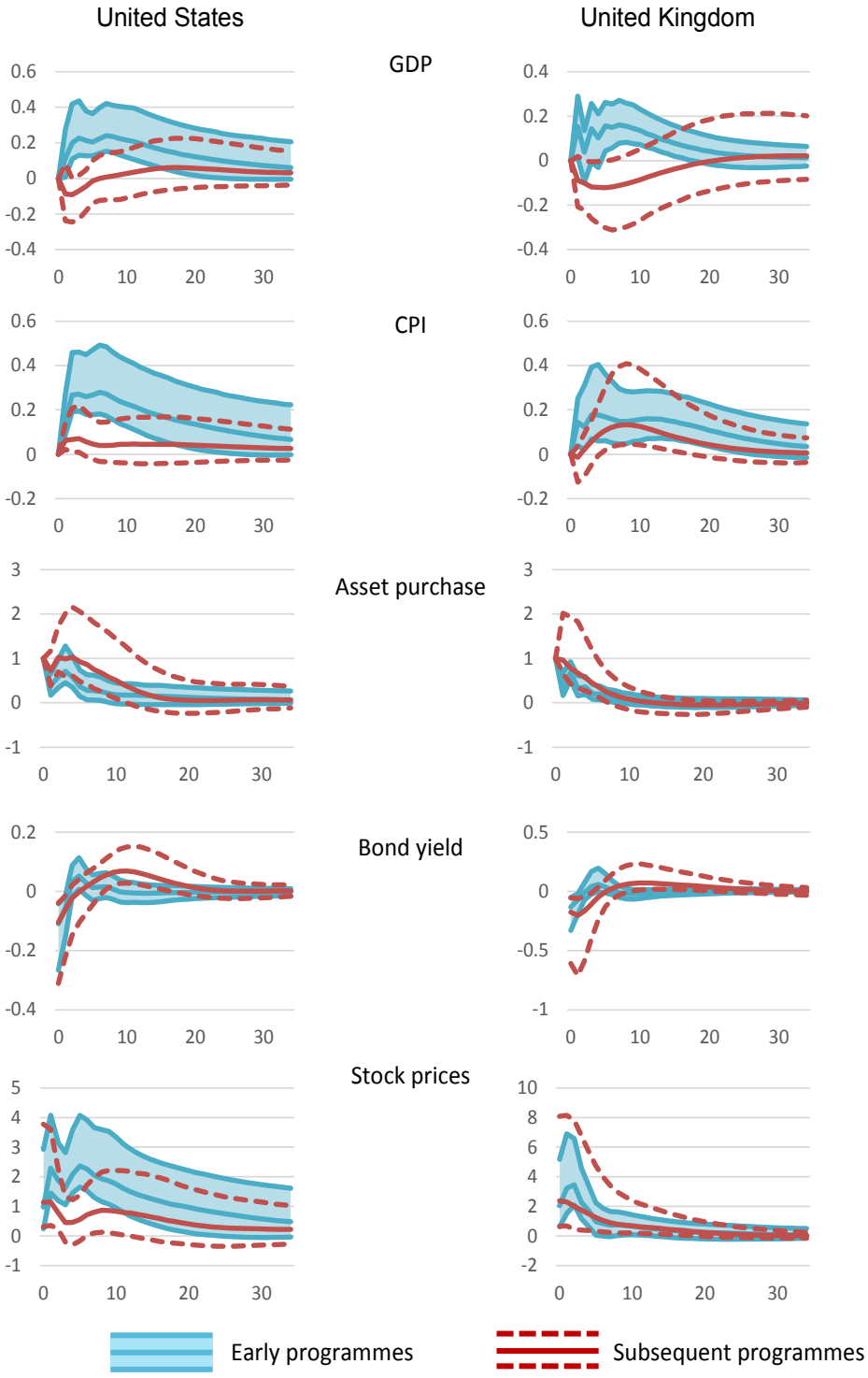
By contrast, we find less pronounced changes in the asset market impact of asset purchase announcement shocks. The bond market impact is in both periods very similar in the United States, while it is somewhat stronger and more persistent in the United Kingdom in the second period. The stock market impact has become quantitatively weaker in both countries, with peak impacts falling from 2.4% to 1.2% in the United States and from 3.5% to 2.4% in the United Kingdom. That said, also in the second period the effects of the shock on stock prices are highly persistent and significantly different from zero.

How do our results compare with those of previous papers? Panizza and Wyplosz (2016) run a whole battery of tests to assess changes in asset purchase effectiveness based on a sample split, including BVARs similar to the ones we have estimated. In contrast to our results, they conclude that the BVAR-based analysis of asset purchase shocks in the United States and the United Kingdom does not yield evidence of decreasing effectiveness of the measures. We see a number of reasons for this discrepancy. First, in Panizza and Wyplosz (2016) the two subsamples overlap, the first ranging from 2009 to 2012 and the second ranging from 2011 to 2016. While such overlapping subsamples increase the number of observations in each sample period, it biases the results against finding changes over time, as Panizza and Wyplosz also acknowledge. We find that this makes a difference mainly for the United States, where we find overlapping error bands for both output and prices when estimated over overlapping subsamples. However, in the second sample period, the effects are still not significantly different from zero. Second, they identify the asset purchase shock using a sign-restrictions-based identification scheme that leaves the impact on output and prices open, while we restrict it to zero for the reasons provided above. This makes a difference for some of the results. For instance, for the United Kingdom, they find the largest GDP effect of the asset purchase shock in the second subsample immediately on impact. Finally, for the United States, there is a different set of assumptions on the size of the asset purchase announcements. Panizza and Wyplosz do not account for MBS purchases, while we do so in our analysis. Moreover, they set the

[10] The sample split leaves us with rather short samples for statistical inference, in particular for the first sample period. Yet, even if a small sample size is seen as a major concern in particular for the first sample period, one can still compare the results for the longer second sample with the full sample results. Such a comparison would reveal the robustness of the findings from the full sample analysis to the exclusion of the early observations. Note that, since we generate the impulse responses using Monte Carlo procedures rather than bootstrapping, the small-sample bias in bootstrapped impulse response confidence bands pointed out by Kilian (1998) is not a concern for us.

size of Federal Reserve's LSAP3 equal to zero, while we set it equal to the ultimately realised size of the programme. As we will see below, our assumption is much closer to what markets expected at the time when the programme was announced.

Figure 5: Impulse responses to an asset purchase announcement shock (split sample)



Median responses with 16th and 84th percentiles error bands. The asset purchase announcement shock is normalised to the size of 1% of annualized Q1 2009 GDP. The sample period for the early programmes runs from 11/2008 to 06/2011 for the United States and from 01/2009 to 06/2011 for the United Kingdom; the sample period for the subsequent programmes runs from 07/2011 to 10/2014 for the United States and to 11/2016 for the United Kingdom.

Haldane et al (2016), also following the set-up of Weale and Wieladek (2016), assess whether the effects of asset purchase announcement shocks depend on the state of financial markets. They find for the United States and to a lesser extent also for the United Kingdom, that asset purchase announcement shocks have large and significant effects when financial market stress is high (between 2007 and early 2010), but that the effects are generally smaller when it is low (since early 2010). Our results are consistent with their findings for the United States, but point to a greater reduction in asset purchase effectiveness also for the United Kingdom. The difference is probably due to the difference in sample split point, which is early 2010 in their case, and mid-2011 in ours.

4. Term spread shocks

One potential reason why the estimated effectiveness of asset purchase programmes has declined is better anticipation of the measures over time. While the early programmes represented entirely new and largely unexpected policy measures, subsequent programmes were probably more routine for markets, and probably also better anticipated in part due to preparatory central bank communication, such as prior speeches hinting at further asset purchases. The approach taken so far, which links the identification of the asset purchase shock to the path of officially announced asset purchases is obviously vulnerable to this caveat. In order to address this point, we replicate the analysis in this section using an alternative specification of the model, linking the identification of the asset purchase shock only to changes in financial market variables, which should also capture anticipation of the programmes by markets.

Specifically, we re-estimate the VAR as a four variables system, excluding the cumulative asset purchase announcement series. We identify a term spread shock using the same restrictions as before (Table 1), except for the ones on the asset purchase announcement series. The shock is therefore identified with the restrictions that it does not have an immediate effect on output and prices, and that it lowers the long-term bond yield and increases real stock prices. Baumeister and Benati (2013), and Kapetanios et al (2013) were the first to analyse the dynamic effects of term spread shocks identified through sign restrictions of this type to assess the effects of central bank asset purchases. Weale and Wieladek (2016) also consider this approach as a robustness check.

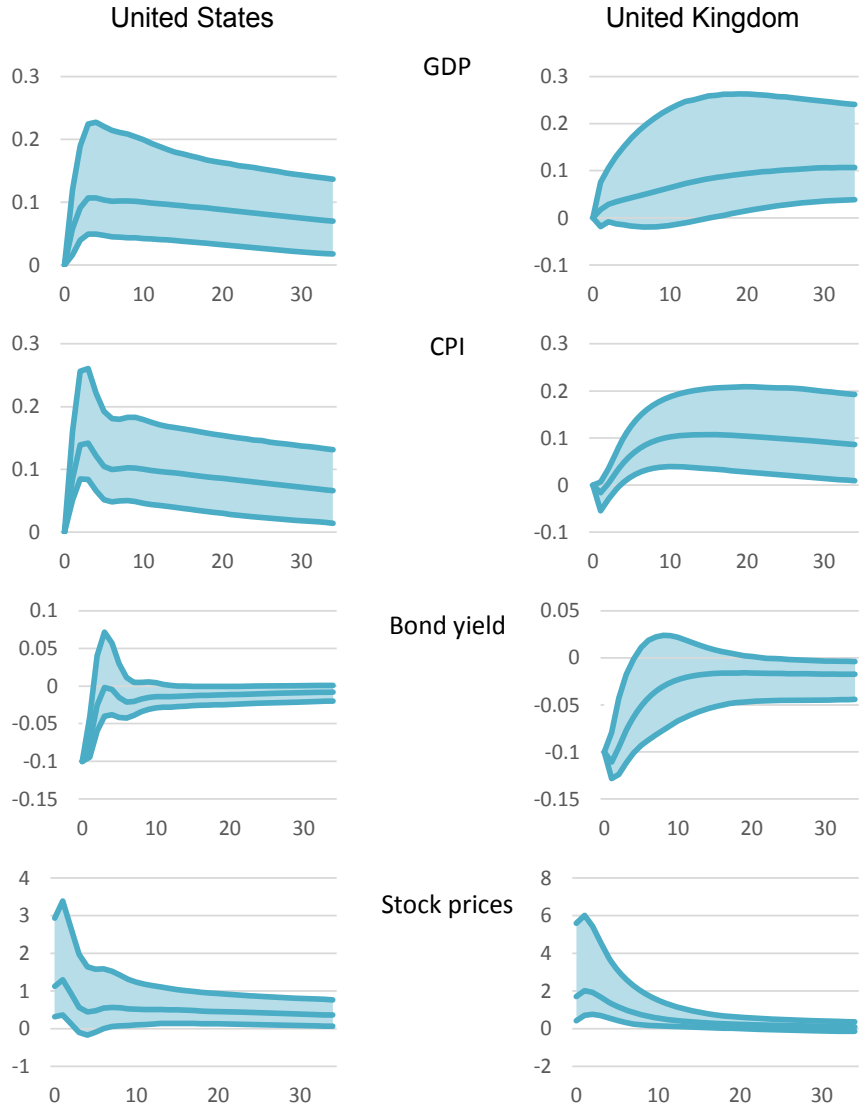
While the analysis of an expansionary term spread shock in principle avoids the problem of better anticipation of asset purchase programmes over time influencing the results, it does not come free of new caveats. In particular, while the term spread shock should capture asset purchase announcements and market expectations thereof, it will in particular also capture forward guidance by central banks on the future path of policy rates over this period.[11] Therefore, the effects of central bank asset purchases are less cleanly identified with this approach. That said, the shock could be interpreted in a broader way, capturing both asset purchases and forward guidance.[12]

[11] For a review of central bank approaches to forward guidance since the GFC, see Filardo and Hofmann (2014) and Borio and Zabai (2016).

[12] Similar caveats would apply if we would use a shadow policy rate as the monetary policy instrument. For instance, the shadow rates from Wu and Xia (2016) are estimated based on a non-linear term structure model and represent, in a nutshell, the implicit level of the policy rate that would be consistent with observable constellations of the yield curve. As such, they should also capture anticipation effects, as well as forward guidance on future policy rates. Panizza and Wyplosz (2016) consider the shadow rate as an alternative indicator of monetary accommodation provided through asset purchases. We refrain from doing so here, however, in part because the shadow rates are estimated based on a constant parameter term structure model. It would therefore seem inconsistent to use this variable to explore changes over time in the macro-financial effects of innovations to asset purchases. That said, we have also run the analysis using the shadow rates and found the results to be qualitatively in line with those obtained based on the four variable system estimated in this section. These results are available upon request.

Figure 6 displays the dynamic effects of a term spread shock over the full sample period, with the shock size normalised to 10 basis points. The results are similar to those for the asset purchase announcement shock. In both the United States and the United Kingdom, we see a significant persistent increase in real GDP and in the CPI of roughly 0.1% at the peak. Real stock prices rise by a maximum of 1.5% in the United States and 2% in the United Kingdom. Thus, also here we find that the stock market impact of asset purchases is a multiple of the macroeconomic impact.

Figure 6: Impulse responses to a term spread shock (full sample)

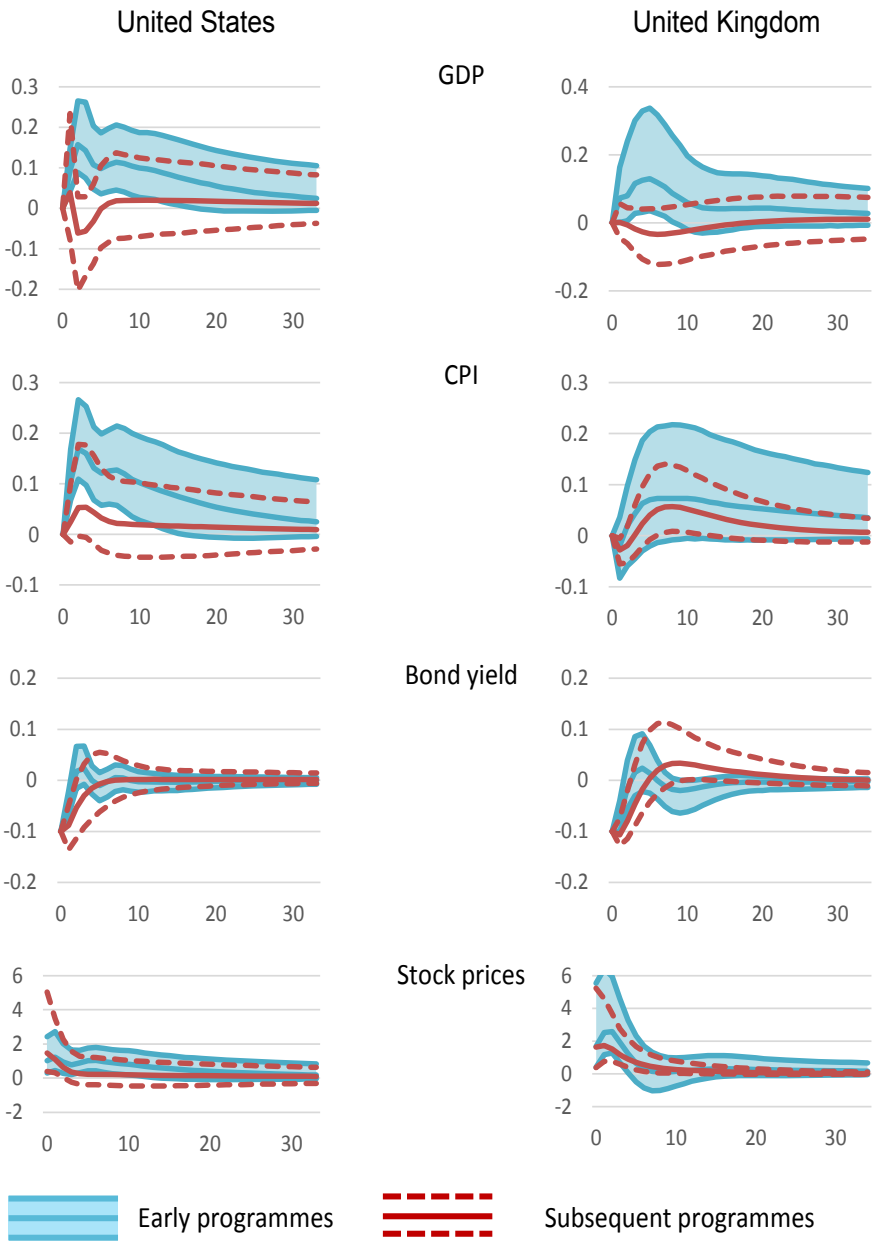


Median responses with 16th and 84th percentiles error bands. The term premium shock is normalised to a 0.1 percentage point decrease in the bond yield. The sample period is 11/2008 to 10/2014 for the United States and 01/2009 to 11/2016 for the United Kingdom.

The results from the subsample estimation, which are reported in Figure 7, confirm the indications of the previous section's analysis. A 10 basis point negative term spread shock has in general significant positive effects on output and prices in the first subsample period, while for the second period the effects are smaller and not significantly different from zero. The differences between the two sample periods' impulse responses are however not as pronounced as for the asset purchase shock and the error bands overlap, with the exception of US real GDP.

By contrast, the peak impact of a term spread shock on stock prices is very similar in the two sample periods. Thus, also here the results suggest that the effects of asset purchases on stock prices have over time become stronger relative to those on the real economy.

Figure 7: Impulse responses to a term spread shock (split sample)



Median responses with 16th and 84th percentiles error bands. The term premium shock is normalised to a 0.1 percentage point decrease in the bond yield. The sample period for the early programmes runs from 11/2008 to 06/2011 for the United States and from 01/2009 to 06/2011 for the United Kingdom; the sample period for the subsequent programmes runs from 07/2011 to 10/2014 for the United States and to 11/2016 for the United Kingdom.

5. Asset purchase expectations

An alternative approach to taking into account anticipation effects is to use measures of the expected size of asset purchases. There are various survey-based sources of market participants' expectations about central bank asset purchase programmes. For instance, for the United States, the Blue Chip survey included questions on the respondents' expectations of asset purchases by the Federal Reserve (Foerster and Cao (2013)). The questions were posed in a way that returned "Yes/No" answers, which therefore provided qualitative information on the respondents' expectations of asset purchases, whether asset purchases would be launched and their expected nature. However, they did not provide any quantitative information about the expected size of the programmes.[13] Reuters conducted ad hoc polls amongst market participants about the Federal Reserves and the Bank of England's asset purchase programmes including questions about the expected size of the purchases. Yet, as far as we know, the results of these surveys are not available in a systematic way that would make it possible to construct a time series of the expected amounts of asset purchases.[14]

In the following, we draw on the Federal Reserve Bank of New York's primary dealer survey to construct a time series of expected asset purchases for LSAP3.15 The outcomes of this survey have been published since January 2011 and have provided primary dealers' expectations of the size of the Federal Reserve's asset purchases in a consistent way since June 2012. While this sample period is shorter than our second sample period and covers only LSAP3, it is still long enough for the analysis to be performed.

In order to quantify the expected size of the open-ended asset purchase programme, we make use of the questions on (1) the expectation of the future size of the Federal Reserve's System Open Market Account (SOMA), and (2) the expectation of the monthly pace and the duration of the purchases. We use the former whenever available, and the latter for periods for which it is not. From the survey answers, we use the median response as the market expectation and we update the series whenever a new survey is available. We keep the values unchanged for months where no survey takes place (months without an FOMC meeting).

Figure 8 shows the time series of the median expected size of LSAP3 from the primary dealer survey obtained that way. The chart shows that the launch of LSAP3 was expected prior to the initial announcement in September 2012 and that the expected size of the programme continued to rise through December 2012 when the open-ended Treasury purchases were announced. Median expectations subsequently rose further during 2013, before dropping back somewhat after the tapering announcement.

We re-run the analysis using the expected asset purchases (again normalised by 2009Q1 nominal GDP as in the exercises before) as the policy proxy. Specifically, we re-estimate the five variable VAR described in Section 2, but including the expected asset purchases instead of the

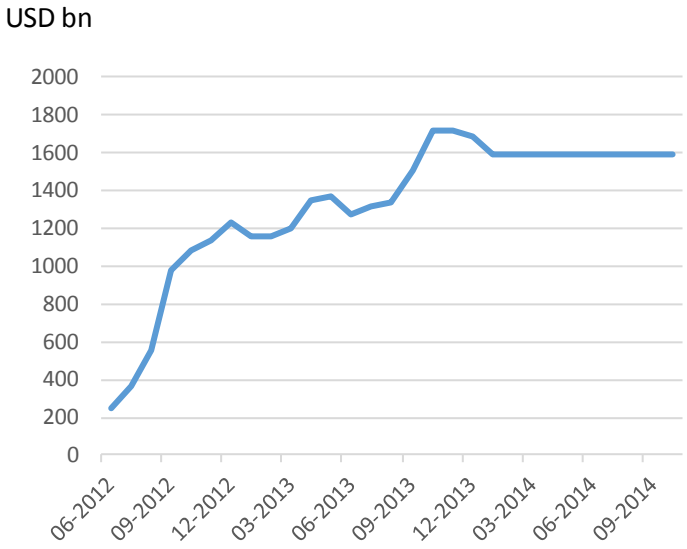
[13] Foerster and Cao (2013) also consider newspaper and internet search-based expectations measures. Specifically, they construct newspaper and internet search indices given by the number of newspaper articles and internet searches containing keywords related to asset purchases. Their empirical analysis suggests that the level of these indices have a negative link to long-term interest rates and to the term premium. This is consistent with the notion that rising expectations of asset purchases, reflected in a larger number of newspaper articles and internet searches on the topic, lower interest rates. However, these indices are of qualitative nature and do not provide any information about the expected size of the programmes.

[14] Joyce et al (2011) and Haldane et al (2016) construct QE surprises as the difference between the average expected size of QE announcements from the Reuters poll participants and the actual announcement of the Bank of England to analyse their financial market impact.

[15] The surveys are available online at https://www.newyorkfed.org/markets/primarydealer_survey_questions.html.

cumulative asset purchase announcements. The sample period is June 2012 to October 2014. We identify an asset purchase expectations shock using the same identifying restrictions that we used to identify the asset purchase announcement shock (Table 1).

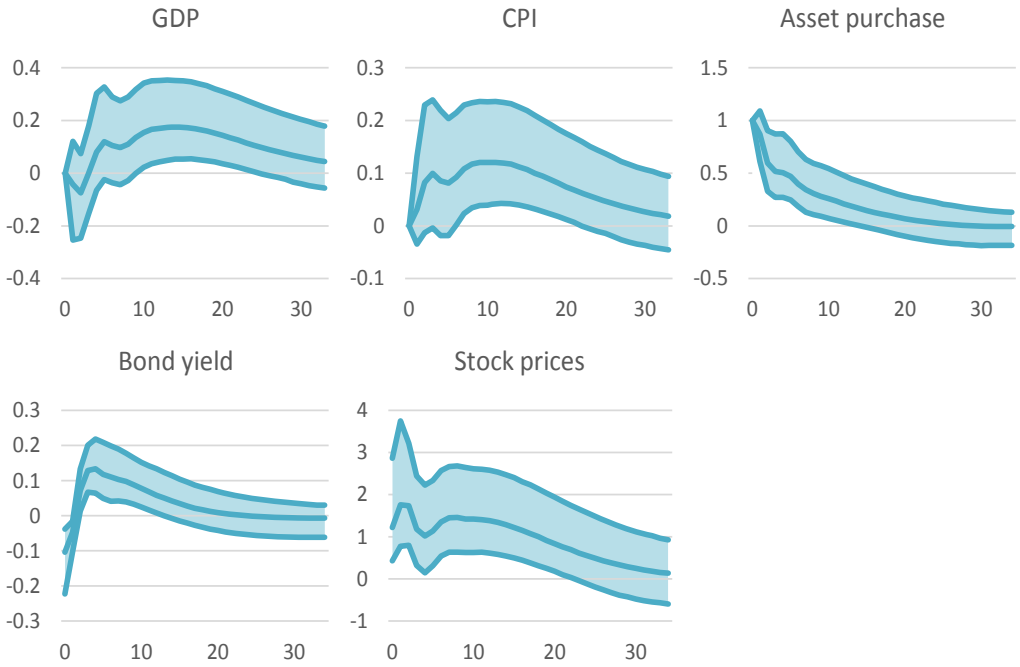
Figure 8: Primary dealers' LSAP3 expectations



The results suggest that controlling for anticipation of asset purchase announcements can restore significant positive macroeconomic effects for LSAP3. Figure 9 shows that an asset purchase expectations shock generates positive macroeconomic effects significantly different from zero. The peak effect on real GDP is 0.18%, while that on the CPI is 0.12%. These effects are somewhat smaller than the ones we previously obtained for the asset purchase announcement shock in first sample period and they are also smaller than those found over the full sample period. However, we cannot really assess whether the effects of asset purchases have changed over time based on the results for the asset purchase expectations shock. For such an assessment, we would need to analyse the effects of the shock for the earlier sample too, which is not possible due to a lack of data on primary dealer expectations.

The asset market effects are similar to those obtained before for the asset purchase announcement shock. The long-term bond yield falls by 10 basis points on impact and then rapidly returns to baseline. Real stock prices display a persistent significant increase, with a peak impact of 1.8%. Thus, also with this specification, we find that the stock market impact of asset purchases is in real terms about 10 times larger than that on real GDP.

Figure 9: Impulse responses to an asset purchase expectations shock in the United States



Median responses with 16th and 84th percentiles error bands. The asset purchase expectations shock is normalised to the size of 1% of annualized Q1 2009 GDP. The sample starts in 06/2012 and ends in 10/2014.

6. Conclusions

Our analysis of shocks to announced asset purchases, which follows Weale and Wieladek (2016), suggests that the Federal Reserve's and the Bank of England's early asset purchase programmes had significant positive macroeconomic effects, while those of the subsequent ones were weaker and in part not significantly different from zero. Similar results obtain for our analysis of term spread shocks in the spirit of Baumeister and Benati (2013) and Kapetanios et al (2013), which should be less vulnerable to changes in anticipation of the programmes over time.

However, when considering shocks to expectations of the Federal Reserve's last asset purchase programme LSAP3 from the Federal Reserve Bank of New York's primary dealer survey, we find significant positive effects on output and prices. This suggests that better anticipation of asset purchase programmes over time may partly explain their measured ineffectiveness during the recovery from the GFC. That said, these estimated effects are smaller than the ones we obtained before for the early asset purchase programmes and they are also smaller than those found over the full sample period.

A second important finding of our analysis is that, in all estimations, there is a significant and persistent positive impact of asset purchase shocks on stock prices. This suggests that central bank asset purchases may have been a driving factor of rising stock market valuations in recent years.

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Annex

Asset purchase announcements by the Federal Reserve and the Bank of England Table A1

Date	Programme	Description
Federal Reserve		
25.11.2008	LSAP1	Purchases of $100 billion in GSE debt and $500 billion in MBS.
18.03.2009	LSAP1	Purchases of $300 billion in long-term Treasuries and of an additional $750 and $100 billion in MBS and GSE debt, respectively.
03.11.2010	LSAP2	Purchases of $600 billion in Treasuries.
21.09.2011	MEP	Purchases of $400 billion of Treasuries with remaining maturities of six to 30 years and sales of an equal amount with remaining maturities of three years or less until June 2012.
20.06.2012	MEP	Extension of the maturity extension program until the end of 2012, amounting to an additional programme size of $267 billion.
13.09.2012	LSAP3	Purchases of $40 billion of MBS per month as long as "the outlook for the labor market does not improve substantially… in the context of price stability".
12.12.2012	LSAP3	Extension of open-ended asset purchases to Treasuries, at a pace of $45 billion per month.
Bank of England		
19.01.2009	APF1	Purchases of up to £50 billion of high quality private sector assets financed by Treasury bill issuance and the DMO's cash management operations.
05.03.2009	APF1	Asset purchases increased to £75 billion, now financed by central bank reserves rather than Treasury bills and including purchases of gilts in the secondary market.
07.05.2009	APF1	Asset purchases increased to £125 billion.
06.08.2009	APF1	Asset purchases increased to £175 billion.
05.11.2009	APF1	Asset purchases increased to £200 billion.
06.10.2011	APF2	Asset purchases increased to £275 billion.
09.02.2012	APF2	Asset purchases increased to £325 billion.
05.07.2012	APF3	Asset purchases increased to £375 billion.
04.08.2016	APF4	Asset purchases increased to £445 billion, including £10 billion in corporate bonds.

QE = Quantitative easing; LSAP = Large-Scale Asset Purchase; GSE = government-sponsored enterprise; MBS = mortgage-backed securities; MEP = Maturity Extension Program; APF = Asset Purchase Facility.

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