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Abstract

One way quantitative easing (QE) purchases of government bonds by central banks may affect the yield curve is by creating scarcity in the purchased securities, leading to an increase in their prices or equivalently a reduction in their yields. We analyse and compare the importance of this so-called 'local supply' (or scarcity) channel across all of the Bank of England's QE government bond purchase programmes during 2009 to 2020. We find strong evidence overall for the role of the local supply channel in explaining gilt yield reactions both to QE announcements ('ex ante'), as well as after purchases have begun ('ex post'). The largest impact on the yield curve through local supply seems to have been in response to the initial QE1 announcements in 2009, both in terms of total impact (the impact of the announced programme), marginal impact (the impact of a given amount of purchases) and relative impact (the proportion of the total change in yields explained). Our findings also imply there may have been an increase in the relative importance of other channels and/or policies over time.

Key words: QE, local supply, preferred habitat, yield curve, monetary policy.

JEL classification: E43, E52, E58, E65, G11, G12.

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1. Introduction

One way QE purchases of government bonds by central banks may affect the yield curve is by creating scarcity in the purchased securities, leading to an increase in their prices or equivalently a reduction in their yields. The scarcity effect of QE government bond purchases is sometimes referred as a local supply effect, as it is concentrated or localized in the bonds being purchased, although it may also spill over to bonds which are closely substitutable.[1]

The theoretical foundations for the local supply channel go back to theories of preferred habitat behaviour and segemented markets of the 1950s and 60s, associated particularly with Modigliani and Sutch (1966) and Culbertson (1957), which were later given more rigorous underpinnings in the theory-based papers by Andres, Lopez Salido and Nelson (2004) and Vayanos and Vila (2009, 2021). For government bond purchases to affect yields through local supply there needs to be some reason that assets are not perfectly substitutable, or more generally that markets are segmented. One way this may happen is if there are preferred habitat investors who value holding default free bonds of specific maturities; for example, in order to match their liabilities or because of regulatory requirements.

There are reasons for thinking that analysing the UK's experience in this context may be particularly instructive. For one thing, the presence of preferred habitat behaviour in the UK government bond (gilt) market is well-documented (see eg Greenwood and Vayanos (2010) and Giese et al (2021)) and this provides a reason for thinking that the role of local supply may be material. Second, the Bank of England has now used QE for more than a decade in a variety of economic and financial conditions, including the global financial crisis, the euro area sovereign crisis and the fallout from the Covid-19 pandemic and the 'dash for cash'.

Our contribution in this paper is to estimate the importance of local supply effects across each of the Bank of England's five QE programmes to date, covering the period from 2009 to 2020. For each programme, we apply a two stage instrumental variable method, similar to the approach used by D'Amico and King (2013) in their analysis of the reaction of US Treasuries to the Federal Reserve's first Large Scale Asset Purchases (LSAP) during 2009-10. Unlike D'Amico and King, who use instrumented purchases and other controls to explain relative yield movements ex post over a single QE programme, we look at subperiods within five QE programmes, which enables us to look at local supply effects over time. We also consider the high frequency reaction of yields to each QE major announcement, an ex ante approach used by D'Amico and Kaminska (2019) in their analysis of the corporate bond yield reactions to the QE programmes during 2009-2016. These ex ante and ex post approaches can be thought of as examining the effects of both expected purchases and actual purchases on supply. We focus exclusively on impact of local supply stock effects - the effects of local supply on bond yields through changes in the expected or actual stock of purchases.[2]

[1]This is conceptually distinct to the impact asset purchases may also have by removing the amount of aggregate duration from the market (the duration risk channel), which should have effects across the term structure that are increasing in maturity (a channel that has received relatively more attention in research of the QE policies by the Federal Reserve (eg Gagnon et al (2011), Li and Wei (2013) and Ihrig et al (2018)) and the ECB (see eg Altavilla et al (2021), Eser et al (2019) and Blattner and Joyce (2020))). Both form an important underpinning for so-called portfolio balance channel (originally associated with Tobin (1961) and others), which is often cited as one of the key transmission mechanisms through which central bank asset purchases, commonly known as QE, worked during and after the global financial crisis (see eg Bernanke (2020) and Bhattarai and Neely (forthcoming) for comprehensive reviews).

[2] The overwhelming evidence from other research on the topic is that effects through the flow of purchases - 'flows' - tend to be much smaller or non-existent (see Kandrac and Schlusche (2013) for the US, De Santis and Holm-Hadulla (2020) for the euro area and Joyce and Tong (2012) for the UK).

We find strong evidence overall for the role of the local supply channel in explaining gilt yield reactions, both ex ante and ex post. We provide three measures to evaluate the yield curve impact through local supply: the marginal impact (the impact of a given amount of purchases), the total impact (the impact of each announced programme), and the relative impact (the proportion of the total change in yields explained by local supply). Our ex ante results suggest that the impact of the local supply channel was strongest in response to the first QE programme (QE1) across each of these criteria and diminished over time. However, the direction of ex post effects explained by local supply over time is less clear, depending on the time horizon examined and the controls included, suggesting that more work is needed to control for potential confounding factors, especially in later programmes.[3]

Related literature: Our paper and other recent research on the local supply effects of QE builds on earlier literature on the impact of debt management on the yield curve; most of it for the United States, with Modigiliani and Sutch (1967) an early example. By and large the main conclusion of much of this work was that any effects on asset returns were small at most (see Hess (1998)). However, most of this literature focused on the impact of small changes in the relative share of government debt, in times of relative market tranquility. The relevance of these results for the large scale asset purchases introduced by central banks in response to the economic and financial crises starting in 2008-09 is therefore questionable.

Of the recent literature on the local supply effects of QE in the US, we have already noted the relevance of the paper by D'Amico and King (2013) to our methodology in this paper. Their own analysis of security-level data on Treasury prices and quantities finds evidence of powerful local supply stock effects during the course of the first LSAP programme in the United States. In another paper, Cahill et al (2013) document the important role of local supply and duration shocks in explaining the high frequency reaction of US yields to five Fed QE announcements, using an approach that allows for pre-announcement changes in market expectations of QE using survey information. They find that both channels are broadly equally important in explaining the transmission of QE purchases. Although the available UK survey data does not enable us to replicate their approach, we nevertheless incorporate information on the news in each QE announcement in some of regression specifications to check their robustness. In a more recent paper, D'Amico and Seida (2020) investigate the role of local supply in explaining high frequency Treasury yield reactions to both QE and Quantitative Tightening (QT) announcements, finding evidence that the effects through local supply remain similarly potent both for loosening and tightening announcements using kinks in the yield curve to identify the impact of local supply. That study focuses exclusively on high frequency reactions to QT and QE announcements. Our approach is rather different, but we find evidence that over longer periods the reaction of yields differs significantly across different programmes.

For the euro area, Altavilla, Carboni, and Motto (2021) augment the methodology developed by D'Amico and King (2013) to include empirical proxies for duration risk and credit risk channels, which they apply to examining security prices in the euro area over the period preceding and following the start of the ECB's Public Sector Purchase Programme (PSPP). They find local supply channels explain a very limited amount of the variation in yields, something they attribute to the calmer market conditions prevailing in the euro area during the QE period they consider. In particular, they only consider ex post analysis over a lengthy two-year period from September 2014 to October 2016 and do not allow for endogeneity between bond returns and the ECB's security purchases. We examine shorter periods and use instrumented purchases to address the endogeneity problem. Finally, Arrata and Nguyen (2017), use security-level data to assess the impact of the ECB's purchase programme on the French bond market, focusing on local supply channels. Using a similar approach to D'Amico

[3] The ex post estimates may differ from the ex ante ones as relative yields may change over time as the distribution of actual purchases becomes known. Confounding factors may also change the shape of the curve.

and King (2013), they find that the cross-section of French bond returns one year after the launch of the PSPP was significantly affected by the stock of PSPP purchases, while there was no impact through the flow of transactions. They also provide evidence that the sell off in euro area bonds in April to July 2015 was associated with a reduction in the expected size of the PSPP.

There are three previous studies of the UK experience that are particularly relevant. Meaning and Zhu (2011) apply the D'Amico and King (2013) ex post methodology to QE1 purchases in the UK, finding there are statistically significant and sizeable effects on yields. Using a different regression approach applied to intraday data around QE1 announcement dates, Joyce and Tong (2012) conclude there were effects through both the local supply and the duration channels, but they do not examine later QE programmes. In a broadly similar approach to Cahill et at (2013), McLaren, Banerjee and Latto (2014) use the impact of changes in the expected distribution of the Bank's gilt purchases resulting from operational changes in the auction maturity buckets during QE1 and QE2 to identify the impact of local supply on gilt yields. Their work suggests that the local supply effect was broadly constant across earlier QE programmes, which is in line with what we find for QE1 March and August. But their work did not look at any QE programmes after 2012 and uses a different methodology that only exploits news to changes to expected "own" supply without taking into account local supply effects more broadly.

The rest of this paper is structured as follows. Section 2 discusses the theoretical underpinnings of local supply effects on asset prices. Section 3 provides some background on the Bank of England's five QE programmes over the last decade, how they were implemented and the immediate gilt yield reaction to six major QE announcements. Section 4 describes our modelling approach and Section 5 turns to our econometric analysis and presents ex ante and ex post results for each separate QE programme. As a first step in formally testing whether local supply impacts varies over time, Annex D describes estimates from a pooled version of the model, analysing effects of each QE programme in a joint framework. Finally, Section 6 provides conclusions and suggestions for further work.

2. Theoretical background

In finance textbooks, net asset supply has no independent role in affecting asset prices (see Cochrane (2001)). Provided there are no frictions and no credit or liquidity risk, conventional theory suggests that bond yields will equal the average of current and expected future short-term interest rates and a risk premium, where the latter reflects the covariance between expected returns on the bond and the representative investor's stochastic discount factor (intertemporal marginal rate of substitution). In this stylised setting, there is no scope for the quantity of central bank asset purchases of individual bonds to have an impact on yields, beyond any impact they have through signalling the central bank's future intentions of policy rates (the QE "signalling channel") (see eg Wallace (1981) and Eggertsson and Woodford (2003)).

The QE neutrality result breaks down in the presence of certain kinds of market or informational friction; see eg Haldane (2016) for a summary. One way in which the quantity of government debt, or more specifically the relative quantitity of different bonds, may matter for yield determination is if there are some investors who have so-called preferred habitats. This is where investors prefer to hold bonds with certain characteristics (eg their maturities) for non-pecuniary reasons independent of risk and return. In this situation bonds become imperfectly substitutable for each other, which gives rise to the possibility that changes in the net supply of bonds will lead to a change in bond prices/yields, as investors require compensation to adjust their stock of asset holdings. It is worth noting that this is a necessary not a sufficient condition. Even if certain investors have preferred maturity habitats, prices/yields will only be sensitive to scarcity in certain gilts if there is some market imperfection that prevents the activities of arbitrageurs offsetting the effects. This may occur if arbitrageurs are capital constrained or more broadly are risk averse. This may vary with market conditions, which may introduce some element of state contingency into the yield curve impact through this channel.

As discussed in Section 1, the literature on preferred habitat goes back to the 1950s and 60s, but a lack of micro foundations and indifferent empirical results meant that mainstream finance theory largely ignored these concepts for many years. Papers by Andres, Lopez Salido, and Nelson (2004)[4] and Vayanos and Vila (2009, updated 2021) were important in reinvigorating work in this area, as of course was the decision of the major central banks to engage in large-scale asset purchase programmes in response to the golbal financial crisis.[5]

Undoubtedly the most widely cited and influential theoretical paper on the topic of preferred habitat and the yield curve is by Vayanos and Vila (2009, 2021), setting out a framework incorporating preferred-habitat investors (who only invest in bonds with specific maturities) and arbitrageurs (who trade between bonds of different maturities but are risk averse, or equivalently capital constrained). The Vayanos-Vila model is instructive as it provides conditions in which there are duration and local supply effects. The duration effect emerges because change in net debt supply - whether brought about by changes in investor demand, new issuance or central bank asset purchases - affects the amount of duration risk arbitrageurs need to hold, leading them to change the risk premium they require for holding it. If the short rate is the only risk factor, this duration effect dominates and shocks to demand have global effects across the term structure wherever they originate. But in the case of multiple risk factors, and where arbitrageurs are highly risk-averse, demand effects are localised and in the limit are restricted to the maturity where they originate (what they call the "segmentation equilibrium"). An implication of the model would be that bond purchases by the central bank would in certain conditions affect yields through both duration and local supply channels. The fact that the relevance of local supply depends on the level of risk aversion of arbitrageurs also suggests that these effects may be state contingent, which might lead to the effects of local supply varying across the various programmes we analyse.

The Vayanos-Vila model provides the broad motivation for our empirical approach which estimates local supply effects from the relationship between changes in the cross-section of yields on individual gilts in response to changes in the distribution of actual and expected QE purchases across gilts, as described in Section 4.

3. The Bank of England's five QE programmes

3.1 Chronology

The Bank of England carried out five QE programmes between March 2009 and the end of 2021, mainly comprising of purchases of UK conventional government securities (gilts) (see chronology in Annex A, Table A).

The Bank announced its first QE programme (QE1) at the height of the global financial crisis in March 2009, when it reduced Bank Rate to 0.5%, which was widely believed at the time to be its lower bound. The initial decision to buy £75 billion of private and public assets over three months was

[4] It is worth pointing out that Andres, Lopez-Salido, and Nelson (2004) do not mention preferred habitat in their paper, but their theoretical model has similar implications, with one group of unrestricted households who can invest in short and long-term bonds and one group who can only invest in long-term bonds. In the literature this sort of set-up is referred to as 'asset market segmentation', rather than preferred habitat.

[5] Bernanke (2020), former Chair of the Federal Reserve, has stressed the importance of preferred habitat as an important argument for QE: "if investors have "preferred habitats" because of specialized expertise, transaction costs, regulations, liquidity preference, or other factors, then changing the net supplies of different securities or classes of securities should affect their relative prices."

subsequently extended, with further purchases announced in May 2009 (£50 billion), August 2009 (£50 billion) and November 2009 (£25 billion). At the conclusion of the programme in January 2010, the Bank had purchased £200 billion of assets, mainly consisting of UK conventional government bonds.

Asset purchases resumed in October 2011 (QE2), during the euro area sovereign debt crisis, when the MPC announced a further £75 billion of gilt purchases. Following an additional £50 billion of gilt purchases announced in February 2012, the programme ended in May 2011. In July 2012, the MPC announced a further round of asset purchases (QE3), which consisted of a further £50 billion of gilt purchases. The QE4 programme announced in August 2016 (QE4), following the referendum on UK EU membership in June that year, consisted of £60 billion of gilt purchases. This accompanied a package of measures, including a Bank Rate cut to 0.25% and a £10 billion programme of corporate bond purchases. Finally, the MPC announced it would expand its QE programme by an additional £200 billion of gilts and corporate bonds on 19th March 2020 in response to market volatility and a global 'dash for cash' in response to the onset of Covid-19. This announcement also accompanied a cut in policy rates from 0.25% to 0.1% and a new Term Funding Scheme with additional incentives for SMEs (TFSME). Further QE expansions of £100 billion and £150 billion of gilt purchases were subsequently announced in June 2020 and November of 2020, with QE5 purchases of £450 billion in total completed in December 2021.

3.2 Implementation

The Bank of England carried out its purchases of gilts through a programme of reverse auctions, which were targeted on buying gilts in different maturity ranges. At the start of QE1, two auctions took place each week: one for gilts with residual maturity of between 5 and 10 years and one for gilts with maturities between and 10 and 25 years (see details in Joyce and Tong (2012)). Mid-way through the QE1 programme in August 2009, the Bank added an extra auction when it decided to extend its buying range to gilts with residual maturity of 3 or more years. These three auctions covered three purchase buckets: 3 to 10 years, 10 to 25 years and 25 years and over. This split of purchases across three buckets continued until the second QE2 announcement in February 2012, when the Bank's auctions were restructured (see Banerjee, Daros, McLaren and Latto (2012)). This meant that the Bank subsequently ran three separate auctions, covering gilts with residual maturities between 3 and 7 years, 7 and 15 years and over 15 years.[6] These three buckets remained in place until QE5 in March 2020, when the buckets were changed to 3 and 7 years, 7 and 20 years and over 20 years.

The significance of the choice of auction purchase ranges for our analysis is that the Bank has had various times indicated that it intended to buy equally across them, which has given market participants some broad guidance on which segments of the market would face greater demand pressure. In practice, the choice of which particular gilts to purchase has been driven by the price of the offers submitted by market participants relative to market prices, and other factors, like the Bank's decision not to hold more than 70% of the free float of any gilt.

3.3 Event study analysis

Figures 1 and 2 illustrate the reaction of gilt yields to what we deem as the most significant QE announcements made by the Bank of England during its five QE programmes. (Our data sources are described in Annex B.) These cover the first official announcement of each QE programme and in the case of QE1 one additional announcement made during the programme. So in all we consider announcements made in March 2009 (QE1:1), August 2009 (QE1:2), in October 2010 (QE2), June 2011 (QE3), August 2016 (QE4) and March 2020 (QE5), where the naming convention is self-

[6] This restructuring reflected a pre-emptive action to avoid potential future issues in gilt market functioning arising from the relative scarcity of gilts in the 10-25 year sector of the free float.

explanatory.[7] In the earlier programmes, and in QE5, these purchases were expected to be completed over 3 to 4 months; while QE4 was expected to be completed (and was completed) over a slightly longer period.

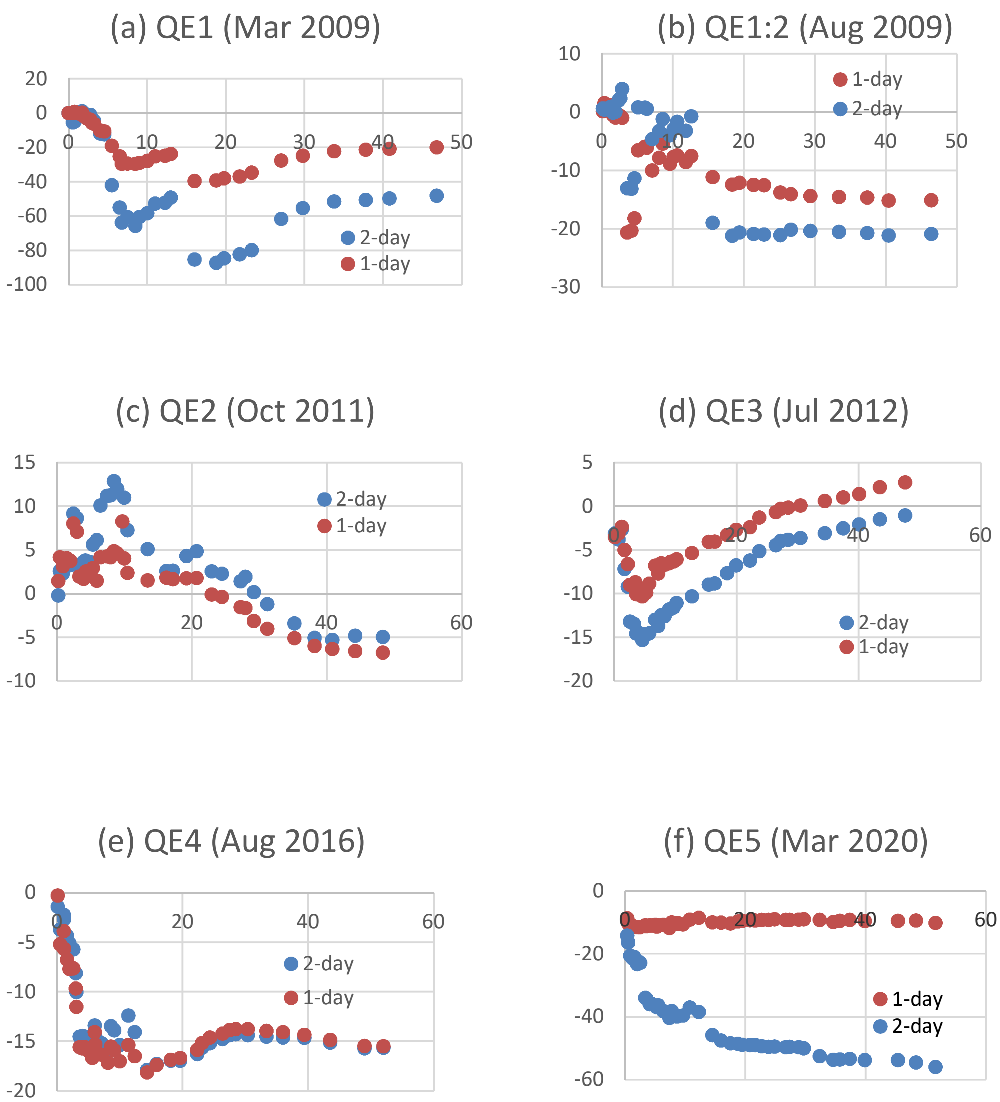
Looking across these various announcement reactions, it is apparent that the average size of the gilt yield reaction varied considerably, with the largest reactions being in response to the first QE announcement of the QE1 programme, followed by the reaction to the first QE5 programme. This can be largely explained by the size of the news in each announcement, as indicated by Figure 2, which shows the association between the immediate reaction of average 5 to 25 year yields and the estimated size of the QE shock, measured using Reuters data and market intelligence.

Interpreting these yield reactions needs some care, as in some cases markets had priced in some of the additional QE before the announcement occurred and there may have been other events that moved yields during the considered 1- and 2- day periods. These confounding factors seem particularly important in QE2 and QE3. The announcement of QE2 was largely expected, with the survey data suggesting that the announced size of purchases was slightly more than market participants had expected. But, although yields fell immediately after the announcement which would be consistent with some upside news, the reaction over the day is clouded by euro area news about the sovereign debt crisis that led to an upward shift in the yield curve shortly after the announcement on the same day. In the case of the QE3, the announcement was smaller than expected, which initially led to a rise in long-maturity yields, but this was offset following a 25bp ECB rate cut an hour later.

However, from the standpoint of assessing the possible role of local supply, it is the distribution of the yield reaction across gilts that is of particular interest. It is apparent that this is far from simply a function of maturity, as might have been expected if transmission was solely through the duration risk channel. Instead for some announcements (notably for QE1 March 2009 and August 2009 and March 2020) there are clear discontinuities in the reaction of the term structure, possibly consistent with information released at the same time on the auction maturity ranges, which would have an effect on yields if there was a local supply channel at work.

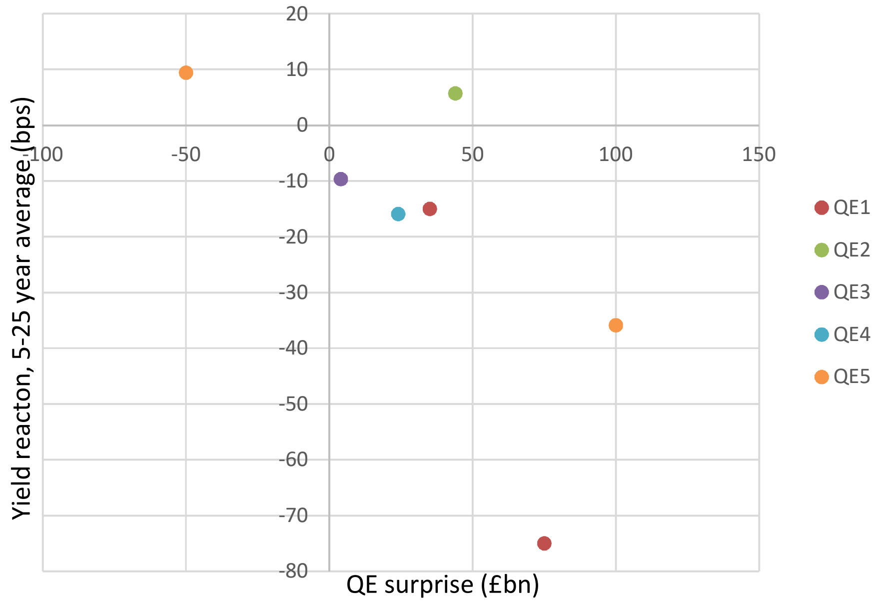
[7] We do not consider the later QE5 announcements as they are more difficult to analyse in our framework. The June 2020 announcement was in line with market expectations, but the announced pace was slower than expected and may have led market participants to expect a smaller overall QE programme. The November 2020 announcement exceeded market expectations, but did not appear to change expectations of QE over the medium term. For further discussion, see Froemel, Joyce and Kaminska (2021).

Figure 1: Gilt yield (1 and 2 day) reactions to six QE Announcements



Note: Vertical axes – in basis points (bps), horizontal axes show maturity in years.
Source: DMO, Tradeweb Markets, author calculations.

Figure 2: Yield reactions vs QE surprises



Source: DMO, Tradeweb Markets, Reuters, author calculations.

4. Modelling approach

To credibly attempt to measure local supply effects, we need to use micro data on individual bonds and their prices/yields. The approach we take is based on the two-step method proposed by D'Amico and King (2013). The basic idea is that the operation of a QE local supply channel should imply there is a negative relationship between QE purchases and relative changes in the cross-section of yields on individual bonds. In order to analyse stock effects,[8] the authors model yield changes across the first LSAP programme in the US using a cross-sectional regression approach. But potential endogeneity between purchases and prices means that to establish causality they use an IV-type regression framework, in order to instrument purchases.[9] This results in a two stage approach, where in the first stage they regress realised cumulative purchases of US Treasuries over the LSAP1 programme on a set of information variables and controls available at the start of the programme and then in a second stage use the predicted values from this regression in a further regression explaining yield changes.

We apply a similar - ex post - approach to examining the Bank of England's QE purchases during its five QE programmes, where we look at yield changes in the months after each initial QE announcement and instrument realised cumulative purchases in a similar way. However, following D'Amico and Kaminska (2019), we also combine this analysis with an additional ex ante approach, where we analyse the immediate reaction of yields to QE announcements by relating them to

[8] The authors also examine flow effects, where they look across QE reverse auctions using a time-series approach, where they do not use this two stage approach.

[9] The precise mechanisms differ in the UK and US due to the implementation of QE. However, as gilts are purchased in reverse auctions in the UK, there is a potential endogeneity stemming from a simultaneity problem, leading to a downward bias of OLS estimates. This is because gilts with higher relative yields may be more likely to be offered (demand-driven), and thus partly offset the impact from purchases (supply-driven).

instrumented future purchases, derived in the same way. We describe this as ex ante, as yields react in expectation of future purchases. In this case, the two step approach in effect provides a way of proxying for the change in expectations about the distribution of purchases in response to each announcement. Arrata and Nguyen (2017) examine the reaction of French bond returns to actual and expected purchases of French bonds during the Eurosystem's PSPP programme over the period January 2015 to March 2016, but use survey data to derive expected purchases.[10]

Setting our empirical framework out in more detail, in the first stage of our approach we regress the change in the Bank of England's QE holdings of each ISIN over the course of an announced QE programme onto information available to market participants immediately prior to the time of the initial announcement. The first stage regression can therefore be written as:

$$q_i = \mu + (\mu_0 + \gamma_0 \frac{Q_{i,t0}}{B_{i,t0}} + \gamma_1 B_{i,t0} + \gamma_2 B_{i,t0}^{sub} + \gamma_3 X_{i,t0}) \times eligible + \epsilon_i \ , \quad (1)$$

where q_i is the total amount of purchases by the BoE of ISIN i over the course of the announced programme relative to the amount outstanding of gilt i and its near substitutes. $\frac{Q_{i,t0}}{B_{i,t0}}$ is the share of the gilt outstanding already held by the BoE in its portfolio, i.e. at time *t0* (where our hypothesis is that the the BoE is less likely to buy gilts already owned in large amounts relative to the market). Expressing QE purchases as a ratio to the amount of debt outstanding allows us to estimate the stock effect of QE purchases relative to the size of the market rather than as an absolute nominal amount, which seems particularly important in examining QE purchases over time, given the large expansion of government debt over this period. It seems intuitive that it is the size of purchases relative to the market matters for the impact on prices/yields. $B_{i,t0}$ is the nominal amount outstanding of gilt i (where our hypothesis is that the quantities purchased depend positively on the amounts outstanding, as measured as of the day before the announcement); and $B_{i,t0}^{sub}$ is the amount of outstanding of near substitutes (where our hypothesis is that the quantities of a particular gilt purchased would depend inversly on the amounts outstanding of similar gilts available for purchase from the market). The buckets of the substitutes are built around each gilt based on its remaining maturity. More specifically, we define as close substitutes: gilts that are within 2 years remaining maturity for gilts maturing in less than 10 years, within 4 years remaining maturity for gilts maturing between 10-40 years, and within 10 years for extra long gilts maturing in more than 40 years. To define substitutes at the long end of the curve, we increase the maturity range to make sure that each gilt has more than one substitute.[11] X_i is a vector of bond characteristics, including the residual maturity of the bond (all as *t0*).

The second stage regresses yield changes on cumulated purchases of each gilt and its near substitutes (ie gilts with similar maturities defined above), using the fitted values for purchases from the first stage:

$$\Delta \mathrm{R}_{\mathrm{i,t}} = \alpha + \beta_1 \widehat{q_i} + \beta_2 \widehat{q_i}^{sub} + Z_i + \varepsilon_i \quad (2)$$

where $\Delta \mathrm{R}_{\mathrm{i,t}}$ is the change in the yield of ISIN i, $\widehat{q_i}$ are the predicted purchases of the same ISIN relative to amounts outstanding of the ISIN and its close substitutes derived from equation (1), $\widehat{q_i}^{sub}$ represents the purchases of the same gilts's near substitutes relative to the amount outstanding of the ISIN and its substitutes and Z_i is a matrix of other controls. (Note that *t* is not fixed, e.g. for the

[10] This approach is thus in spirit of Cahill et al.'s (2013) bond-specific news shocks, but in the absence of market intelligence about gilt-specific purchase expectations. Note that the counterfactual to this expectation is zero purchases.

[11] We also experimented with a defining the relevant substitutes more narrowly or broadly. For the most part our main results were robust to different definitions.

immediate reaction of yields t could cover one day, ie *t = t0 + 1*, while for the ex-post analysis *t* could indicate the window covering period from the announcement until the end of purchases).

5. Estimation results for each programme

In this section, we document our estimates of QE local supply effects using the two-stage approach described in Section 4, which we apply to both the immediate reaction of yields to the Bank of England's QE announcements and to the longer-term reaction of gilt yields over the course of each programme. We also test the robustness of our findings by rescaling QE purchases across each programme by the amount of 'news' in each of the QE announcements implied by contemporaneous survey data and available intelligence from the Bank's market contacts. The rest of the section is focussed on the second stage results, while the underlying first stage results are presented in the Annex C.

5.1 Ex ante effects

Table 1A shows the results of the second stage regressions for the ex ante impact of the QE local supply channel on yields for our baseline model specification, see equation (2) in section 4.

In addition to own purchases and substitute purchases, these regressions also include maturity and maturity squared as controls. One reason for including these controls is to capture potential **duration channel effects**, which may come about as QE purchases reduce the amount of duration risk that the market needs to absorb, leading to a reduction in the price of duration risk demanded by arbitrageurs (a gilt market-wide channel). Since longer-dated gilts carry more duration risk, this should lead to yield reductions that are increasing in maturity. Controlling for maturity may help capture some of this effect, although it may also capture other factors that change the shape of the term structure.[12]

The regression coefficients reported in Table 1A are based on regressions that measure the gilt yield reaction to each announcement over a 2-day window (i.e. where yield changes $\boldsymbol{\Delta R_{i,t}}$ are measured at time *t = t0 + 2*); the corresponding regression results for the 1-day change in yields are reported in Annex C.[13] Before describing these results, note that for the QE1 March and QE1 August announcements, we report two different regression specifications in Tables 1A and 1B, where fitted purchases relate to purchases over different horizons. Over the shorter horizon, the regressions relate yield changes to fitted purchases over the period until the next MPC decision on QE was announced (from March 2009 to just before the May 2009 decision and from August 2009 to just before the November 2009 decision), while the longer horizon results relate to purchases over six month periods (between March 2009 and just before the August 2009 decision and from August 2009 to just before the November 2009 decision). On balance, we prefer the regressions based on purchases over a shorter horizon, as instrumented purchases over a longer period are likely to be less related to the immediate reaction of yields, as they will reflect further MPC announcements and potentially other confounding events. This is also consistent with the generally smaller local supply coefficients we obtain for the corresponding second stage regressions. Note also that the tables exclude reactions to the QE2 and QE3,[14] following our earlier discussion in Section 3, which

[12] For example, McLaren, Banerjee and Latto (2014) point out how the signalling channel could impact yields in the opposite way across the term structure, thus conflating the overall effect. In our regressions, we use the linear quadratic formulation of maturity instead of duration itself to capture duration effects, similar to D'Amico and King (2013).

[13] We calculate these windows using cob to cob data, apart from the case of the March QE5 announcement, where we use 2pm on the day of the announcement as the reference point, as yields rose materially during the morning of the announcement. Regression estimates for these specifications are not shown here for conciseness. The stage 1 regressions estimates are reported in Annex C.

[14] We include QE2 and QE3 in the ex post analysis, however, where the effects of confounding news in the daily event windows should be relatively less important.

suggested that the 1-day and 2-day yield changes either did not accurately reflect the QE reaction because of other news during the event windows.

Turning to the regression results in Table 1A, these show that the average marginal yield impact of a given amount of purchases of a particular gilt (the coefficient shown on 'QE own') was negative and statistically significant for all the QE announcements we examine. The largest own effect, however, was for the QE1 announcements in March 2009 and August 2009, with the effects for the QE4 and QE5 announcements substantially smaller. Broader supply effects, through a portfolio rebalancing mechanism, also come through purchases of close substitutes, with these effects also slightly larger in response to the QE1 announcements. The impact of maturity in these regressions is broadly in line with the workings of a duration channel, with larger yields falls at longer maturities, and this maturity effect declining in the level of maturity (indicated by the negative sign of the squared term). But as discussed earlier it is also possible that maturity is picking up other factors.

In Table 1B, we summarise what the results in Table 1A mean for the impact through own supply (defined as the impact on a specific gilt of purchasing it) and local supply (the combined effect of the impact on a specific gilt of purchases of this bond and the effect through purchases of its substitutes). It is evident that the impacts through own supply and local supply were largest in response to the QE1 announcements. The absolute impact of local supply in basis points was largest following the QE1 March announcement, with overall local supply explaining nearly half of the overall yield impact. In the case of the August QE1 announcement, local supply more than explains all of the yield reaction, although the yield change itself was rather smaller. In the later QE4 and QE5 programmes, however, the ex ante impact through local supply was much smaller, explaining 20% of the 2-day change in yields in QE4 and less than 10% in QE5.

Table 1A: Second-stage regressions, gilt yield changes in a two-day window around the announcement as a function of expected QE purchases, controlling for maturity ("duration") effects

	QE 1 Mar-May	**QE 1 Mar-Aug**	**QE 1 Aug-Nov**	**QE 1 Aug-Jan**	**QE 4**	**QE 5 Mar**
Purchases own, $\widehat{q_i}$ (%)	-523.557***	-254.917***	-549.344***	-387.389***	-67.712*	-47.951***
Purchases subs, $\widehat{q_i}^{sub}$ (%)	-71.405***	-33.370***	-54.850**	-40.001**	-38.698***	-14.429**
Maturity	-4.974***	-4.381***	-0.519*	-0.303	-0.405***	-1.470***
Maturity squared	0.084***	0.070***	0.017***	0.012**	0.005**	0.018***
Constant	10.332***	9.432***	5.774***	5.352***	-6.392***	-22.532***
Observations	30	30	32	32	40	42
R2 (adj)	0.913	0.940	0.833	0.827	0.596	0.920

Notes: The regressions include gilts with residual maturities above 1 year (except for QE1 Mar-May and Mar-Aug, where it refers to above 3 and below 29 years). The horizon for QE5 (March – July) is chosen to be consistent with QE survey expectations based on Reuters surveys available for early 2020. The dependent variable is the change in yields on the announcement day, in basis points. QE own refers to cumulative purchases of a gilt and QE subs to cumulative purchases of gilts in its bucket of substitutes, expressed relative to the corresponding amounts outstanding, constructed from the first stage regression discussed in text. Statistical significance at 10%, 5% and 1% levels is denoted by *, ** and ***, respectively. Actual refers to average yield change over period; local supply impact refers to yield change attributed to the local supply channel. Local supply impact numbers are rounded from the original figures.

Table 1B: Second-stage regressions, summary of own and local supply impacts on gilt yields over one day (square brackets) and two day windows around the QE announcement, as a function of expected QE purchases, controlling for maturity ("duration") effects

	QE 1 Mar-May	**QE 1 Mar-Aug**	**QE 1 Aug-Nov**	**QE 1 Aug-Jan**	**QE 4**	**QE 5 Mar**
Impact own supply (bps)	-17 [-7]	-21 [-8]	-13 [-11]	-13 [-11]	-1 [-1]	-1 [-0]
Impact actual eligible (bps)	-65 [-30]		-12 [-12]		-15 [-15]	-45 [-10]
Impact local supply (bps)	-24 [-10]	-29 [-12]	-16 [-13]	-16 [-13]	-3 [-3]	-3 [0]
Impact actual all (bps)	-54 [-26]		-9 [-10]		-13 [-14]	-43 [-10]
% explained own supply	**27 [23]**	**32 [28]**	**110 [90]**	**112 [91]**	**6 [5]**	**3 [2]**
% explained local supply	**45 [40]**	**54 [47]**	**171 [135]**	**177 [139]**	**20 [20]**	**8 [0]**
Memo items:						
Avg purchase own	0.0331	0.0820	0.0233	0.0340	0.0132	0.0299
Avg purchase subs	0.0994	0.243	0.0540	0.0798	0.0443	0.128

Notes: See notes to Table 1. *Actual* refers to average yield change over period; *own supply* impact refers to impact on yields through own purchases; *local supply* impact refers to yield change attributed to the local supply channel that is the result of own and substitute purchases. Impact numbers are rounded from original figures.

In Table 2, we expand our second stage regression specification to control for gilt-specific liquidity (bid-ask spreads), as well as maturity. The strength of the impact of QE purchases on yields is often linked with market stress (on the QE liquidity channel, see eg Bailey et al (2020)). QE purchases might be expected to improve liquidity conditions in the gilt market, which will depress liquidity premia, with the largest effects on the most illiquid bonds. This should be picked up in bid-ask spreads, a common measure of illiquidity. However, it is worth noting that longer-dated gilts also tend to be less liquid, so this measure of liquidity will also be correlated with duration, so some impact through this channel may also be attributed to maturity. At the same time, however, an impact through bid-ask spreads might also be consistent with a local supply channel, if more illiquid gilts are viewed as less substitutable for others.[15]

[15] McLaren, Banerjee and Latto (2014) argue along these lines in their analysis of the local supply channel.

Table 2: Second-stage regressions, gilt yield changes in a two-day window around the announcement as a function of expected QE purchases, controlling for liquidity and duration effects

	QE 1 Mar-May	QE 1 Mar-Aug	QE 1 Aug-Nov	QE 1 Aug-Jan	QE 4	QE 5 Mar
Purchases own, $\hat{q}_i$ (%)	-508.608***	-222.363***	-514.403***	-373.232***	-68.367*	-48.777**
Purchases subs, $\hat{q}_i^{sub}$ (%)	-71.783**	-35.821***	-51.226*	-37.736*	-38.895***	-15.041**
Maturity	-5.192***	-5.245***	-0.543*	-0.289	-0.400***	-1.460***
Maturity squared	0.087***	0.084***	0.017***	0.011*	0.005**	0.018***
BA spread	1.802	6.774	-.116	-.248	-.044	0.051
Constant	6.811	-3.676	5.785***	5.603***	-6.342***	-22.720***
Observations	30	30	32	32	40	42
R2 (adj)	0.909	0.924	0.817	0.817	0.586	0.919

Notes: See notes for Table 1A. The bid-ask spread (BA spread) is defined in price space as the percentage difference between bid and ask prices divided by the mid-price. Statistical significance at 10%, 5% and 1% levels is denoted by *, ** and ***, respectively.

Table 2 shows that our main results in Table 1A are largely unaffected by the inclusion of bid-ask spreads. The results in Table 2 tend to show that bid-ask spreads are sometimes positively signed (suggesting that there was a smaller yield reduction for more illiquid gilts), but never statistically significant. Moreover, the inclusion of this measure of illiquidity has little impact on the estimated local supply effects or for the effects of maturity. This may be due to the correlation between maturity and our liquidity measure. So it is difficult to be confident that there is no impact through the liquidity channel. The main point we take away, however, is that the presence of the local supply channel is robust to the inclusion of bid-ask spreads or duration proxies.

5.2 Rescaling the results by QE 'news'

The two-stage approach we use in section 5.1 relates the change in the cross-section of yields to instrumented future gilt purchases. An alternative approach would be to relate yield changes to the incremental 'news' about future asset purchases, which might be smaller than the announced purchases if markets were already expecting additional QE. Relating the yield impact to the amount of news in each announcement, rather than to total actual purchases announced, might imply a different message about the relative potency of the local supply channel across different programmes if the amount of news differed materially.[16]

[16] In our methodology, not accounting for the amount of news would lead us to *underestimate* the local supply effect, as the purchases reflect changes in expectations of the distribution of purchases.

The available survey data for the UK do not allow us to construct QE news at the ISIN level (eg, as Cahill et al (2013) do for the US). However, as a crude alternative, we can use information on the aggregate amount of QE news at the time of each announcement, as estimated from survey data and market intelligence, to rescale the actual purchases of each ISIN over each QE programme.[17] We can work out the scaled impact by dividing the coefficients by the percentage of news.

Intuitively, if a given QE announcement carries less news, the unexpected amount of purchases used to explain the same movement in yields will be smaller and thus the marginal impact coefficient will increase. This is what we see in Table 3. All the coefficients are larger as the news in each announcement was smaller than the amount announced, according to survey evidence and intelligence based on the Bank's market contacts. The message of the relative potency of local supply effects across different programmes remains largely unchanged, however. The scaled own and total local supply effects in QE1 are considerably larger than in QE4 or QE5.[18]

Table 3: Marginal effects when scaled by news of QE announcement

		QE1 March-May	QE1 August-Nov	QE4	QE5 March
APF own, $\hat{q}_i$	Unscaled	-523.557***	-549.344***	-67.712*	-47.951***
	Scaled	-872.595***	-915.573***	-169.28*	-95.902***
APF subs, $\hat{q}_i^{sub}$	Unscaled	-71.405***	-54.850**	-38.698***	-14.429**
	Scaled	-119.008***	-78.357**	-96.745***	-28.858**
Memo item: % news		60%	70%	40%	50%

Source: Reuters, author calculations based on regression specifications in equation (2) and Table 2. Statistical significance at 10%, 5% and 1% levels is denoted by *, ** and ***, respectively.

5.3 Ex post effects

We can also analyse the impact of local supply over longer time periods by rerunning the regressions for each programme and changing the time interval used to measure the change in yields. Some papers (eg D'Amico and King (2013) and Altavilla et al (2021)) focus on ex post results for the change in yields over the entire length of each QE programme. One potential difficulty with this approach is that the included controls may not adequately account for all the other factors driving yields (including macro economic conditions and fiscal policy) over a lengthy period. In periods where there is unexpected additional debt issuance, for example, we would tend to underestimate supply

[17] This method will not capture occasions where the Bank surprised the market by announcing a change to the purchase ranges it was using.
[18] In this simple approach, only the marginal impact estimate changes. We hold the absolute effect constant but assume that market participants only respond to the amount of news in the announcement, which is distributed proportionally across gilts.

effects. This is because our instrumented purchases rely on information that is available prior to the announcement of the programme and assume that markets expect purchases to be proportional to the amount outstanding at the time of the announcement. An increase in the amount outstanding of a particular gilt that is not expected at this point in time might lead market participants to adjust their expectations about the yield of this gilt relative to the market curve, as well as change the amount of purchases of this gilt they expect relative to other gilts, given the APF's strategy of purchasing evenly across maturity segments ex post. Moreover, it also seems likely that over time yield changes due to local supply effects will be slowly arbitraged away, as noted by Arrata and Nguyen (2017). Given these concerns and for the sake of comparability across programmes with different lengths, we examine ex post results over the both the full programme and over shorter time intervals. We also examine the robustness of our results by adding controls for the influence of other domestic and overseas factors.

Table 4 shows the results when the regressions span the full programme of each QE round. Maturity terms are again included to control for duration-type effects, although they may also partly capture macroeconomic factors that drive changes in the shape of the yield curve to some extent. Here it is noticeable that the identified local supply effects are more similar across programmes than we find for the ex ante results, with the own supply effects consistently negatively signed and statistically significant across all QE programmes, apart from QE4. [19] It remains the case that the total and relative importance of the local supply channel peaks in QE1, however, and there still seems a decline in the relative importance of this channel over time.

That said, there are reasons for treating the results for QE4 and QE5 with particular caution. This is because the purchase programme during QE4 extended significantly longer than the other programme sub-periods we examine, and fiscal issuance increased significantly during the QE5 programme announced in March 2020. In both periods therefore macroeconomic conditions changed materially as the purchases continued. To lend more confidence in the results, it is useful to compare them in the first instance to estimates over a shorter 1 month period. Table 5 shows, however, that overall the main messages from the end of the programme results still hold for the shorter 1 month period, in that the largest own purchase effects occur in QE1, but there also some interesting differences. The sign of local supply effects in QE4 changes and becomes negative in line with our priors and the size and significance of effects through substitute purchases is larger for QE1.[20]

As a further robustness check, we reran the same regressions with duration-matched Overnight Index Swap (OIS) rates and US Treasury yields included separately as control variables. The idea of including OIS rates was to control for other domestic factors affecting gilt yields, including other QE channels like signalling and uncertainty. OIS rates should be affected by changes in policy rates expectations and risk premia in the same way as gilt yields, but they should be largely unaffected by demand/supply imbalances caused by asset purchases, ie local supply effects. In contrast, including US yields allows us to control for the influence of international factors driving gilt yields, which will be largely independent of UK unconventional monetary policy. Table 6 shows the corresponding

[19] The significant macro-political events that unfolded from October 2016 onwards may explain this, as the yield curve shows a sharp reversal in level and slope which we are not able to control for satisfactorily. The local supply coefficients for QE4 are estimated to be negative and statistically significant up to the 2-months horizon, ie before the yield curve shift occurs. We discuss the 1-month results below.

[20] See the discussion in Bailey et al. (2020) on QE during periods of market dysfunction.

regression results over each full programme when these controls are included (the 1-month results are not reported for reasons of space). Including these additional controls increases the size and/or statistical significance of local supply for the March 2009 programme (and the QE3 programme), but tends to reduce it for other programmes. These results suggest it may be important to allow for other macro-financial controls, when judging the importance of local supply effects over longer periods, but further work is required to examine this more systematically.

Table 4: Second-stage regressions, gilt yield changes at the end of each programme

	QE 1 Mar-May	QE 1 Mar-Aug	QE 1 Aug-Nov	QE 1 Aug-Jan	QE 2 Oct-May	QE2 Oct - Feb	QE 3	QE 4	QE 5 Mar
APF own, $\widehat{q_\iota}$	-245.081*	-45.439	-776.682**	-749.398*	-414.996***	-277.847	-439.067***	264.334***	-114.945***
APF subs, $\widehat{q_\iota}^{sub}$	4.340	14.812	-117.378	-80.277	-107.775***	-61.334	-107.088***	87.705***	-61.791***
Maturity	-2.336***	-3.029**	2.592***	7.291***	2.202***	2.191***	1.093***	2.689***	-2.147***
Maturity squared	0.037**	0.046	-0.030*	-0.118***	-0.016**	-0.034***	-0.018***	-0.041***	0.036***
Constant	18.828***	37.767***	-42.797***	-59.351***	-32.614***	-33.183***	-3.360**	-17.592***	-36.579***
Observations	30	30	32	32	35	35	36	40	42
R-squared	0.584	0.459	0.243	0.512	0.868	0.662	0.819	0.924	0.790
R2 (adj)	0.518	0.372	0.131	0.439	0.850	0.617	0.796	0.915	0.767

Notes: See notes for Table 1. Statistical significance at 10%, 5% and 1% levels is denoted by *, ** and ***, respectively. Actual refers to average yield change over period; own supply refers to the yield change attributed to own supply; local supply impact refers to yield change attributed to own and substitute purchases. Local supply impact numbers are rounded and based on original figures.

Table 5: Evidence for local supply effects after 1-month and at the end of each programme

		QE 1 Mar-May	QE 1 Mar-Aug	QE 1 Aug-Nov	QE 1 Aug-Jan	QE 2 Oct-May	QE2 Oct - Feb	QE 3	QE 4	QE 5 Mar
Marginal impact own	1 month	-327.633**	-173.140***	-748.256***	-524.379**	-45.392	-117.798	-313.624***	-133.421***	-120.088***
	End	-245.081*	-45.439	-776.682**	-749.398*	-414.996***	-277.847	-439.067***	264.334***	-114.945***
Marginal impact subs	1 month	-76.288**	-33.203***	-125.971*	-83.341*	-14.569	-23.088	-72.961***	17.605**	-56.998***
	End	4.340	14.812	-117.378	-80.277	-107.775***	-61.334	-107.088***	87.705***	-61.791***
Impact own supply (bps)	1 month	-10.83	-14.20	-17.45	-17.81	0	0	-2.905	-1.765	-3.591
	End	-8.102	0	-18.11	-25.45	-12.85	0	-4.067	n.a.	-3.437
Impact actual eligible (bps)	1 month	-26.34	-26.34	-35.38	-35.38	-7.779	-7.779	-16.37	-18.09	-64.70
	End	-13.07	7.638	-35.43	-15.19	-27.98	-21.19	-2.048	n.a.	-72.31
Impact local supply (bps)	1 month	-18.42	-22.26	-24.26	-24.46	0	0	-5.769	-0.986	-10.90
	End	-8.102	0	-18.11	-25.45	-24.18	0	-8.271	n.a.	-11.36
Impact actual all (bps)	1 month	-14.48	-14.48	-36.66	-36.66	-7.658	-7.658	-16.59	-15.99	-59.62
	End	-4.984	16.74	-38.56	-25.19	-27.87	-21.67	-1.943	14.48	-68.05
% explained own supply	1 month	41.12	53.92	49.32	50.33	0	0	17.74	9.757	5.550
	End	62	0	51.12	167.5	45.93	0	198.6	18.45	4.753
% explained local supply	1 month	127.2	153.7	66.17	66.71	0	0	34.78	6.164	18.28
	End	162.6	0	46.97	101	86.78	0	425.6	n.a.	16.69

Notes: See Table 5 and text. Statistical significance at 10%, 5% and 1% levels is denoted by *, ** and ***, respectively. Actual refers to average yield change over period; *own supply* refers to the yield change attributed to own supply; *local supply* impact refers to yield change attributed to own and substitute purchases. Local supply impact numbers are rounded and based on original figures.

Table 6: Evidence for local supply effects at the end of each programme, results controlling for OIS rates and US yields

	Additional controls	QE 1 Mar-May	QE 1 Mar-Aug	QE 1 Aug-Nov	QE 1 Aug-Jan	QE 2 Oct-May	QE2 Oct - Feb	QE 3	QE 4	QE 5 Mar
Marginal impact own	OIS	-497.994***	-197.569***	-243.613	68.602	-164.804	-37.598	-572.105***	67.079	-14.102
	US yields	-374.717**	-226.004***	-582.218*	33.460	23.503	-91.164	-468.976***	-62.487	-35.802*
Marginal impact subs	OIS	-89.892**	-42.795***	-67.439	-22.090	-52.497*	11.709	-160.460***	60.158**	14.299
	US yields	-41.509	-63.668***	-136.752	-39.170	-5.071	-7.629	-114.829***	8.557	5.036
Impact own supply (bps)	OIS	-16.46	-16.21	0	0	0	0	-5.299	0	0
	US yields	-12.39	-18.54	-13.58	0	0	0	-4.344	0	-1.070
Impact actual eligible (bps)	n.a.	-13.07	7.638	-35.43	-15.19	-27.98	-21.19	-2.048	18.95	-72.31
Impact local supply (bps)	OIS	-25.40	-26.59	0	0	-5.546	0	-11.63	3.163	0
	US yields	-12.39	-33.99	-13.58	0	0	0	-8.872	0	-1.070
Impact actual all (bps)	n.a.	-4.984	16.74	-38.56	-25.19	-27.87	-21.67	-1.943	14.48	-68.05

Notes: See Table 5 and text. Statistical significance at 10%, 5% and 1% levels is denoted by *, ** and ***, respectively. Actual refers to average yield change over period; *own supply* refers to the yield change attributed to own supply; *local supply* impact refers to yield change attributed to own and substitute purchases. Local supply impact numbers are rounded and based on original figure

6. Conclusions

In this paper, we use a variety of regression specifications based on a two-step estimation approach to estimate the importance of the local supply channel in explaining the reaction of gilt yields to Bank of England QE announcements across its five QE programmes.

We find strong evidence overall for the role of the local supply channel in explaining gilt yield reactions both after QE announcements (ex ante), as well as after purchases have begun (ex post). The largest impact on the yield curve through local supply seems to have been in response to the initial QE1 announcements in 2009, both in terms of total impact (the impact of each announced programme), marginal impact (the impact of a given amount of purchases) and relative impact (the proportion of the total change in yields explained). Our ex ante findings suggest these effects diminished in later QE rounds, also implying there was an increase in the relative importance of other channels and/or policies over time. Our ex post results are also broadly consistent with these conclusions, although the sensitivity of the results to additional control variables suggests further work is necessary to fully account for changes in macro-financial conditions over the course of each QE programme.

While our results can be taken as broadly supportive of the notion that the local supply channel varies across programmes and circumstances (consistent with the notion of "state contingency"), isolating the role of specific factors in driving the importance of local supply effects remains an important topic for future QE research.

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Annex A: Chronology of UK QE

Table A:

	DATE	EVENT
	19 January 2009	The Chancellor of the Exchequer announces that the Bank of England will set up an asset purchase programme, initially to be financed using Treasury Bills and the DMO's cash management operations.
	30 January 2009	APF Fund established
	5 February 2009	Bank Rate reduced from 1.5 to 1 per cent
	11 February 2009	February Inflation Report and associated press conference gives strong indication that QE asset purchases are likely
	13 February 2009	First purchases of commercial paper begin
QE1		
	5 March 2009	Bank Rate reduced from 1 to 0.5 per cent. The MPC announces it will purchase £75 billion of assets over 3 months funded by the issue of central bank money. Conventional gilts likely to constitute the majority of purchases. Purchases split between two auction maturity sectors for gilts with remaining maturities of: (a) 5–10 years and (b) 10–25 years
	11 March 2009	First gilt purchases begin
	25 March 2009	First purchases of corporate bonds begin.
	7 May 2009	The MPC announces that QE asset purchases will be extended by £50 billion to £125 billion
	3 August 2009	Secured commercial paper facility launched
	6 August 2009	The MPC announces that QE asset purchases will be extended by £50 billion to £175 billion.The buying range is to be extended to all conventional gilts with a residual maturity greater than 3 years. Purchases split between three auction maturity sectors: (a) 3–10 years (b) 10–25 years (c) Greater than 25 years The Bank announces a gilt lending programme, which allows counterparties to borrow gilts from the APF's portfolio via the DMO in return for a fee and alternative gilts as collateral
	5 November 2009	The MPC announces that QE asset purchases will be extended by £25 billion to £200 billion
	22 December 2009	The Bank announces that it will act as a seller, as well as a buyer, of corporate bonds in the secondary market
	8 January 2010.	First sales of corporate bonds.
	26 January 2010	Final gilt purchases
	4 February 2010	The MPC announces that QE asset purchases will be maintained at £200 billion. The Chancellor authorizes the Bank to continue to transact in private-sector assets, with further purchases financed by issuance of Treasury Bills.

Table A: Chronology of UK QE cont.

QE2		
	6 October 2011	The MPC announces that QE asset purchases will be extended by £75 billion to £275 billion. Market Notice states that: "The Bank intends to purchase evenly across the three gilt maturity sectors."
	10 October 2011	First gilt purchases of QE2 begin
	9 February 2012	The MPC announces that QE asset purchases will be extended by £50 billion to £325 billion.The three auction maturity ranges are changed to gilts with remaining maturities of: 3–7 years; 7–15 years; and Greater than 15 years
	2 May 2012	Final QE2 purchases
	10 May 2012	The MPC announces that QE asset purchases will be maintained at £325 billion
QE3		
	5 July 2012	The MPC announces that the QE asset purchases will be extended by £50 billion to £375 billion
	31 October 2012	Final QE3 purchases
QE4		
	23 June 2016	EU referendum, announced 24 June
	4 August 2016	The MPC announces an expansion of the asset purchase scheme for UK government bonds of £60 billion, taking the total stock of these asset purchases to £435 billion. These purchases form part of a package also including: a 25 basis point cut in Bank Rate to 0.25%; a new Term Funding Scheme to reinforce the pass-through of the cut in Bank Rate; and the purchase of up to £10 billion of UK corporate bonds.
	13 March 2017	Final QE4 gilt purchases
QE5		
	19 March 2020	The MPC announced it the decision to expand its QE programme by £200 billion and cut Bank Rate to 0.1% at a time of unprecedented market dysfunction and volatility as the Covid-19 crisis took hold. The subsequent Market Notice announced that "the Bank intends – at least initially – to make purchases at a materially higher pace than in the recent past" and that the three auction maturity ranges will be changed to gilts with remaining maturities of: 3–7 years, 7–20 years and greater than 20 years.
	18 June 2020	The MPC made a further decision expand its QE by a further £100 billion, while slowing the pace of purchases.
	5 November 2020	The MPC decided to further expand the stock of purchases by £150 billion, taking the target QE stock of gilt holdings to £875 billion. It was also announced that the new purchase programme would start in January 2021 and be completed by around the end of 2021, a much longer purchase period than for previous QE programmes.
	15 December 2021	Final QE5 gilt purchases

Annex B: Data sources

This section explains the data used in our analysis and the sources used.

Gilt yields, maturity, duration and amount outstanding

Data on gilt yields to maturity, and duration are publicly available from the Debt Management Office for the first four QE programmes from their dataset on Historical Prices and Yields.[21] The data on gilt yields are end-of-day reference values for each business day. Duration data is modified duration that is calculated by the DMO and provided in the same dataset. For the fifth QE programme we use gilt yields and duration data from Tradeweb Markets. We construct maturity as the annualised time to redemption date for each date according to the DMO's Gilts in Issue report.[22] Information on amounts outstanding is also available from the DMO website on a daily basis.[23]

Bank of England gilt holdings

Data on gilt holdings come from the Bank of England Asset Purchase Facility's results and usage data.[24] The nominal value of each gilt purchase are available on both a trade and settlement date basis and we calculate current APF holdings as the cumulative purchases up to each date.[25]

Bid-ask spreads

Bid-ask spread data are daily COB data on bid and ask prices from Bloomberg L.P.

[21] Website as of February 1, 2022: https://www.dmo.gov.uk/data/gilt-market/historical-prices-and-yields/

[22] Website as of February 1, 2022: https://www.dmo.gov.uk/data/pdfdatareport?reportCode=D1A

[23] Website as of February 1, 2022: https://dmo.gov.uk/data/pdfdatareport?reportCode=D1A

[24] Website as of February 1, 2022: https://www.bankofengland.co.uk/markets/bank-of-england-market-operations-guide/results-and-usage-data

[25] There is only a small difference between the market and the nominal value of gilt purchases over time.

Annex C – Additional regression results

Table C1: Estimated purchases: QE purchases (own) as a function of amount outstanding, current (relative) APF holdings and controls

	QE 1 Mar-May	QE 1 Mar-Aug	QE 2 Aug-Nov	QE 2 Aug-Jan	QE 2 Oct-May	QE2 Oct – Feb	QE 3	QE 4	QE 5 Mar
APF holdings, $\frac{Q_{i,t0}}{B_{i,t0}}$			-0.0417*	-0.0300*	-0.0521**	-0.0312**	-0.0101	-0.0418***	-0.1231***
AO own, $B_{i,t0}$ **(£bn)**	0.1510**	0.2214*	0.1087*	0.0761*	-0.0062	0.0038	0.0142	0.0505*	0.0365
AO subs, $B_{i,t0}^{sub}$ **(£bn)**	-0.0423**	-0.1016***	-0.0047	-0.0023	-0.0330***	-0.0132*	-0.0125**	-0.0173***	-0.0652***
Maturity	0.0007	-0.0019	0.0017	0.0009	-0.0025*	-0.0004	-0.0009	-0.0019***	-0.0062***
Maturity squared	-0.0001	-0.0000	-0.0000	0.0000	0.0000**	0.0000	0.0000	0.0000*	0.0001***
Eligible	0.0484*	0.1510**			0.1010***	0.0403**	0.0358*	0.0613***	0.2273***
Observations	30	30	32	32	35	35	36	40	42
R2 (adj)	0.764	0.790	0.546	0.583	0.576	0.612	0.241	0.540	0.543
F-statistic	19.79	22.86	8.442	9.665	8.709	9.940	2.847	8.617	9.131

Notes: Results of equation (1) regressions. The regressions include gilts with residual maturities above 1 years. The dependent variable, q_i, is the cumulative purchases over the respective QE round. **AO own** refers to amount outstanding of a gilt and **AO subs** to amount outstanding of gilts in the bucket of substitutes constructed from first stage regression discussed in text. Statistical significance at 10%, 5% and 1% levels is denoted by *, ** and ***, respectively.

Table C2: Second-stage regressions, gilt yield changes on the day of announcement as a function of expected QE purchases, controlling for maturity ("duration") effects

	QE 1 Mar-May	QE 1 Mar-Aug	QE 1 Aug-Nov	QE 1 Aug-Jan	QE 4	QE 5 Mar
Purchases own, $\hat{q}_i$ (%)	-210.947***	-101.658***	-451.041***	-312.158***	-60.878*	-7.131***
Purchases subs, $\hat{q}_i^{sub}$(%)	-33.400***	-15.636***	-45.304*	-33.870*	-45.799***	2.545***
Maturity	-2.126***	-1.882***	0.089	0.260	-0.249***	0.156***
Maturity squared	0.038***	0.032***	0.008	0.003	0.003	-0.002***
Constant	1.688	1.299	-2.309	-2.621	-8.310***	-11.930***
Observations	30	30	32	32	40	42
R2 (adj)	0.909	0.933	0.537	0.517	0.600	0.838

Notes: See notes for Table 1. Statistical significance at 10%, 5% and 1% levels is denoted by *, ** and ***, respectively. Actual refers to average yield change over period; own supply refers to the yield change attributed to own supply; local supply impact refers to yield change attributed to own and substitute purchases. Local supply impact numbers are rounded and based on original figures.

Annex D – Pooled estimation results

Our cross-section analysis for the UK is limited by a lack of observations compared to the US and euro, reflecting the smaller relative number of outstanding government bonds. In this section, we pool across QE rounds, which allows us to make a first step in formally testing whether the local supply impacts varied over time.[26]

Table D shows the regression results across various specifications, which differ principally according to the period that the dependent variable (the change in the gilt yields) is defined over and which programmes are excluded. The coefficients are all relative to the QE1 March-May results, so the point estimates in the ex ante and ex post regressions are equal to the baseline regression estimates reported in Tables 1A and 5. In this instance, we use unscaled purchases for the ex ante results. They are qualitatively similar when scaling them as in Table 3.

The results suggest that QE1 announcements had the strongest immediate impact through local supply effects. After one day, QE1 August had a larger own supply effect, but this is no longer the case after two days, which would be consistent with the findings in Joyce and Tong (2012). The local supply impact through substitutes is also significant and negative, but despite a weaker estimated impact in QE5 March does not seem to have declined significantly in QE4.

The ex post results do not show such a clear pattern, as was the case for the individual regressions. While the first QE programme also appears to have had a stronger impact over a one month horizon, QE2 and Q5 appear to have had larger impact through substitutes. As in the individual regressions,

[26] In ongoing work, we are exploring how different strategies of exploiting time-varying information sets to estimate changes in purchase expectations across programmes (in the Stage 1 regressions) impact the local supply estimates, as well as including additional (macro-level) controls in the Stage 2 regressions.

point estimates in programmes after March are larger except for QE5, but not significant in this setup.

Table D: Local supply effects across programmes: results from pooled regressions

	Ex ante results		**Ex post results**	
	1-day	2-day	1-month	end of programme
Purchases own, $\hat{q}_i$ (%) - QE1 March-May	**-210.947*****	**-523.557*****	**-327.633*****	**-245.081****
QE 1 August - November	-245.876***	101.488	-201.188	-257.058
QE 2			**282.241****	-169.915
QE 3			14.009	-193.986
QE 4	**150.069*****	**455.845*****	194.212	509.415***
QE 5	**203.816*****	**475.606*****	**207.544*****	130.136
Purchases subs, $\hat{q}_i^{sub}$ (%) - QE1 March-May	-33.400***	-71.405***	-76.288***	4.340
QE 1 August - November	-29.558	34.502	11.703	-40.471
QE 2			61.719**	**-112.115*****
QE 3			3.327	-111.428
QE 4	-12.398	32.707	93.893***	83.365*
QE 5	**35.945*****	**56.976*****	19.291	**-66.131****
Observations	144	144	215	215
R2 (adjusted)	0.88	0.95	0.93	0.93