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QUANTITATIVE TIGHTENING AROUND THE GLOBE: WHAT HAVE WE LEARNED?

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ABSTRACT

This paper uses the recent cross-country experience with quantitative tightening (QT) to assess the impact of shrinking central bank balance sheets. We analyze the experience in seven advanced economies (Australia, Canada, Euro area, New Zealand, Sweden, UK and US)—documenting different strategies and the substantive reduction in central bank balance sheets that has already occurred. Then we assess the macroeconomic and financial impact of QT announcements on yields and a range of other market prices. QT announcements increase government bond yields, steepening the yield curve and potentially signaling a greater commitment to raising policy interest rates, but have more limited effects on most other financial market indicators. Active QT has a larger impact than passive QT, particularly on longer maturities. The implementation of QT has been associated with a modest rise in overnight funding spreads and a decline in the "convenience yield" of government bonds, but QT transactions did not significantly affect the pricing and market liquidity of government debt securities. Finally, we evaluate who buys assets when central banks unwind balance sheets, an issue which will become increasingly important if central banks continue to reduce their security holdings while government debt issuance remains elevated. We find that increased demand by domestic nonbanks has largely compensated for reduced bond holdings by central banks. This series of cross-country results suggests that QT has had more of an impact than "paint drying", but far less than simply reversing the effects of the quantitative easing programs launched during periods of market stress. Looking ahead, although QT has been smooth to date, frictions could increase in the future so that QT quickly evolves into more like watching "water boil".

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1. Introduction

As quantitative easing (QE) evolved from being viewed as an "unconventional tool" to becoming part of the standard toolkit for many central banks, an extensive body of research has attempted to measure the impact of these large-scale asset purchases.[1] In contrast, there has been almost no research assessing the impact of unwinding these asset holdings, i.e., quantitative tightening (QT), as only one country had made meaningful progress before 2020 (the US from 2017-2019).[2] Starting in 2022, however, a number of central banks started QT programs. This paper uses these recent experiences to provide the first cross-country assessment of QT. It finds that QT has had some significant effects—such as QT announcements corresponding to a small increase in government bond yields and QT implementation corresponding to a modest rise in overnight funding spreads and a reduction in the "convenience yield" of government debt. By most other measures, however, the effects of QT have been very small (or nonexistent) on average, statistically insignificant to date, and much less than the impact of previous QE programs (in reverse). Domestic nonbanks have largely stepped in to make up for the reduction in central bank bond holdings. Although these modest effects of QT may not persist as excess liquidity is absorbed, QT programs have proceeded smoothly so far, and the insights from this recent cross-country experience should be valuable when central banks weigh adjustments to their balance sheets in the future.

When central banks began using QE in response to the 2008 Global Financial Crisis and subsequent European Debt Crisis, the asset purchases were intended to be temporary.[3] Central banks planned to start unwinding these bond purchases once the economic recovery was on track and soon after they started raising policy interest rates, initially by allowing passive run off of the securities as they expired and then possibly through active sales. This intent to unwind at least some of the securities purchased during QE (even if balance sheets did not fully shrink to pre-QE levels) was important to show the bond purchases were designed for unique periods when the policy rate was at the effective lower bound and not to finance government deficits or permanently support asset prices.

The slow recovery and sub-par inflation after the 2008 crisis, however, combined with uncertainty about how QT would affect the economy, caused most central banks to delay unwinding their asset purchases throughout the 2010s. If the effects of QT were comparable to those of QE (with the sign reversed), unwinding asset holdings could derail the tepid recovery and prevent central banks from raising interest rates much above their lower bounds. In the US, the one country to make progress with QT, balance sheet reduction initially appeared to have minimal effect, but then was blamed for a sharp tightening of funding conditions that forced the US to return to balance sheet expansion sooner than expected. As a result, when central banks

[1] For a summary of this extensive literature, see the 2018 USMPF paper by Greenlaw, Hamilton, Harris and West.
[2] For analysis of the impact of QT in the US from 2017-2019, see D'Amico and Seida (2022), Smith and Valcarcel (2022) and Ludvigson (2023).
[3] Japan used QE from 2001-2006, but this tool was not used more widely until the Global Financial Crisis.

launched even larger QE programs in 2020 in response to the pandemic, there was little discussion of how or when any QT would occur; central banks believed they would have several years before any recovery was strong enough to meaningfully reduce their QE-related security holdings.

The situation changed abruptly in 2021. As economic activity bounced back and inflation spiked, central banks realized that they needed to tighten monetary policy faster and by more than previously expected. This provided the opportunity to accelerate the introduction of QT despite substantial uncertainty about its effects. Even if QT led to a significant tightening in financial conditions or had other contractionary effects, it would no longer constrain the ability of central banks to raise interest rates meaningfully above zero.[4] If the contractionary effects of QT were large, it could even imply slightly less aggressive increases in short-term interest rates, reducing the risks from unexpected, rapid rate hikes and distributing the adjustment across sectors more exposed to the medium- and longer- end of the yield curve.[5] If the contractionary effects of QT were small and did not substitute for rate hikes, central banks could at least reduce political concerns about large balance sheets and the fiscal costs of large securities holdings in a higher interest rate environment. Moreover, if QT began to have meaningful negative effects on market functioning, it could be paused or ended, as occurred in 2019.

This combination of factors prompted a number of central banks to begin publicly discussing, and then implementing, QT programs. In February 2022, the Bank of England (BoE) was the first to start QT when it raised its policy rate to 50bps; it had previously delivered guidance that when the policy rate reached this level, it would trigger the start of QT in the form of the BoE ceasing purchases of expiring government bonds.[6] Six other central banks in advanced economies subsequently announced the start of QT in 2022: the Reserve Bank of New Zealand (RBNZ), Sveriges Riksbank (Riksbank), Bank of Canada (BoC), Reserve Bank of Australia (RBA), Federal Reserve (the "Fed"[7]) and the European Central Bank (ECB). By the end of 2023, these seven central banks had all made meaningful progress in reducing their balance sheets.

This paper assesses the impact of QT programs in these seven central banks to date[8]. Section 2 begins with a detailed description of how each central bank has approached QT since 2021, as well as the Fed experience with QT from 2017-2019[9]. We start by comparing the evolution of

[4] For estimates of the substitutability between balance sheet reduction and policy rate hikes, see Crawley et al. (2022) and Wei (2022).
[5] See Forbes (2021).
[6] The automatic trigger of QT had an opt-out clause that it would occur "if appropriate given economic circumstances". See the BoE's *Monetary Policy Report* from August 2021, Box A, for more details.
[7] In the US, the Federal Open Market Committee (FOMC) makes decisions regarding QT (not the Federal Reserve Board of Governors). To simplify language, we will simply refer to the "Fed" throughout.
[8] The analysis focuses on the unwinding of central bank bond holdings that were purchased as part of QE programs. We do not incorporate any simultaneous adjustments to other lending and liquidity support programs, such as the ECB's TLTROs, the BoE's TFSME. See details in Appendix A1 and A2.
[9] The Riksbank announced the start of QT in April 2019, but made minimal progress reducing its balance sheet before restarting asset purchases in response to the pandemic. Therefore, we include this additional episode of

central bank balance sheets from their peaks, including how they communicated plans for balance sheet reduction and then how they structured and implemented their QT programs. This includes a detailed timeline of key announcements, events and strategies for each country—a resource that should be useful for future research. Some of the parameters that vary across QT programs include: whether to slow the extent of passive run-off through caps (e.g., the US and initially Sweden), whether to actively sell bonds (e.g., New Zealand, Sweden and the UK) and whether to also unwind holdings of corporate and other non-government securities. We document substantial progress shrinking balance sheets in some of these countries through end-2023—such as the 40% reduction in aggregate security holdings in Canada and Sweden, 25% reduction in New Zealand, and 15% reduction in the US and UK. We end this section with projections of how asset holdings would evolve over the next two years if economic and financial conditions allow QT in these seven central banks to continue under existing program parameters. These projections show considerable variation in the extent to which central banks will normalize their balance sheets. The BoC, BoE, RBNZ, and Riksbank are on track to unwind around 80% or more of their QE purchases by end-2025, while the Fed and RBA will unwind only about 50% of the increase in their asset holdings since the pandemic, and the ECB even less.

Section 3 then shifts to analyzing the impact of QT announcements in these seven central banks on government bond yields and a range of other financial indicators. It uses an event-study approach that incorporates the information from QT announcements across countries as well as over time, allowing us to control for other economic news and simultaneous surprises in interest rate decisions. This panel approach is useful to not only evaluate the impact of QT announcements in general, but also to estimate the impact of different types of announcements, of different forms of QT (e.g., active vs. passive), for different types of securities, and in different countries.

The results suggest that individual QT announcements (broadly defined) correspond to a small but significant increase of about 4-8 bps in government bond yields at horizons of 1 year and longer. When these effects are aggregated by country from 2021-2023, the cumulative effect is an increase in government bond yields of 20-26 bps on average (for horizons of 1 year and longer), although there is substantial heterogeneity across countries and the characteristics of the QT program. These effects are substantially smaller than comparable estimates of the impact of all QE announcements (with the opposite sign), but more comparable (although usually still smaller) than the limited QE announcements during non-stressed financial conditions. These effects of QT announcements on yields are larger for "*Main Announcements"* (which involve concrete information about the start or details of a QT program[10]), for announcements involving active bond sales (as compared to passive balance sheet runoff), and when QT includes government bonds. The effects of QT announcements on a range of other

pre-pandemic QT in our analysis of QT announcements (Section 3), but not in the other sections of the paper analyzing changes in the balance sheet, QT implementation, or the corresponding flow of funds.

[10] In contrast, QT announcements with respect to "*Preliminary Discussions"* (which are vaguer discussions about general principles for QT or the potential for QT at an indeterminate date in the future) have no significant effects.

financial market indicators (including equity markets, corporate bond markets, the exchange rate, inflation compensation measures and government bond convenience yields) generally point in the direction of a tightening in financial conditions, but are usually statistically insignificant. The noteworthy exceptions are that QT announcements usually correspond to a significant decline in the corporate bond index and government bond convenience yield. There are not enough observations to assess the impact of slowing or stopping QT, although the US announcement in March 2019 that it would wind down QT earlier than expected corresponded to a fall in yields at all horizons and adjustments in a range of other financial measures.

This analysis also provides some suggestive evidence on the channels through which QT announcements impact yields. Part of the effect of QT announcements on yields corresponds to changes in expectations about policy interest rates over the next 3-6 months (even when the QT announcements were widely expected). This is consistent with QT announcements being interpreted as a signal of a stronger central bank commitment to tightening monetary policy, a link mentioned by some central banks at the start of QT, and similar to the way in which QE works partly through signaling a commitment to keeping the policy interest rate low[11]. This signaling effect of QT, however, may also reflect other forward guidance that occurred at the same time as QT announcements, including stronger language committing to tighter policy and price stability (although it does not seem to reflect any surprises in decisions about the current policy interest rate or other economic news around the date of the QT announcement). As such, the actual impact of QT may be somewhat smaller than we identify in our baseline setup[12]. QT also appears to affect yields by increasing the term spread, especially for active QT, which has a larger impact on longer-term yields. In contrast, passive QT appears to have a larger impact on shorter-term yields. Finally, QT announcements have very small spillover effects on other countries (particularly bond yields, stock and corporate bond indices, and broader financial conditions).

Next, Section 4 shifts from analyzing QT announcements to the impact of implementing QT, i.e., when central banks actually reduce their asset holdings. To analyze these effects, we compile detailed information on the individual assets held in the portfolios of six of the central banks in our sample, as well as their major asset and liability items, after the pandemic as well as for the Fed from 2017-2019. Then we estimate the impact of changes in these portfolios on measures of pricing and liquidity in domestic money markets and government bond markets. We do not find significant pricing effects around the narrow QT implementation dates. More specifically, changes in government bond yields are not significantly different on QT dates as compared to non-QT dates. In addition, when countries sell bonds through active QT, there is no significant difference in the yield dynamics between securities that are actively sold versus similar securities that are not sold by central banks on the same date. Overall, for the narrow

[11] For research highlighting the signaling role of asset purchases, see Krishnamurthy and Vissing-Jorgensen (2011), Bauer and Rudebusch (2014), and Bhattarai et al. (2015).

[12] We attempt to assess any such bias in extensions by controlling for changes in policy expectations. This reduces the estimated effects of QT at shorter horizons, but has minimal impact on longer duration yields or from *Active* QT.

implementation windows, we do not find evidence that QT has distorted pricing of government bonds in the secondary market.

Over time, however, the implementation of QT has resulted in significant reductions in the total assets of central banks and the liquidity balance of banking sectors.[13] This decline in the liquidity balance is generally associated with a significant rise in the spread between overnight funding rates and the central bank deposit rate. The one exception to these findings is for post-pandemic QT in the US; in this case, the decline in the Fed's securities holdings has corresponded to a decline in the overnight reverse repo (ON RRP) balance of nonbanks. As a result, reserve balances at banks have been little changed (so far) and the spread between the federal funds rate and the interest rate on reserves has been steady, even though U.S. repo rates have been trending up recently. Furthermore, we find that the "convenience yield" of government bonds, measured as the spread between the interest rate swap rate and the government bond yield of the same maturity (i.e., the swap spread), has declined since the start of QT. In panel regressions, this swap spread decreases meaningfully when the share of outstanding government bonds held by central banks falls and when the supply of government bonds increases. This suggests that government bonds became less "convenient" under QT.

This section closes by switching from the effects of QT on bond prices to effects on the liquidity of government bond markets and the demand from government bond auctions. We measure liquidity in the government bond market with the Bloomberg government bond liquidity index (based on the yield-curve fitting errors of individual government securities) and measure the demand appetite for government bonds during QT with the bid-to-cover ratio from government auctions. We find a deterioration in government bond liquidity recently, but this deterioration is more tightly correlated with elevated interest rate volatility rather than with QT. In addition, we find that the bid-to-cover ratio has either stayed unchanged or slightly increased during QT, suggesting that QT has not weakened demand at government bond auctions.

Section 5 then shifts to better understanding these changes in the demand for government bonds as central banks reduce their holdings under QT. In order to analyze these dynamics, we leverage data from the IMF and country-specific sources on government security holdings by different investor groups. Panel regressions using the IMF data find some evidence that certain investor groups respond differently during QT than non-QT periods. In particular, nonbank domestic investors absorb an important share of the changes in central bank holdings over all periods, but absorb even more during QT. In the US, this change in the behavior of domestic nonbanks was stronger for the post-pandemic QT than the earlier QT from 2017-2019. The evidence of changes in the behavior of other investor types during QT is heterogeneous across economies, although in several countries foreigners (including the official sector as well as banks and nonbanks) have played an important role substituting for central bank securities holdings.

[13] The one exception is New Zealand, where the decline in QT securities holdings was largely offset by an increase in other asset items, including an increase in foreign currency securities and repo lending by the RBNZ.

Next, this section uses more detailed country-level data to conduct a deep-dive into these changes in demand for government securities in the domestic nonbank sector during QT. In the US, the investor group "households" (which includes hedge funds) has been a particularly important replacement for the Fed's security unwind during QT. Patterns are less conclusive in other economies. A counterfactual analysis for the US confirms that "households" tend to purchase more government securities in response to a reduction in the Fed's share during QT than would be predicted by non-QT periods, while foreign investors (most likely foreign central banks), tend to reduce holdings alongside the Fed. While these results suggest a change in investor behavior during QT episodes, we would caution against a causal interpretation of these findings. In all cases outside of the US, the results rely on a single QT period that occurred over less than two years and which coincided with an aggressive tightening of monetary policy—a development that likely contributed to the documented shifts in investor shares.

To conclude, while this paper's analysis should provide central banks with a useful resource for understanding the impact of unwinding asset purchases, the results are also subject to several important caveats. First, almost all of the QT events in this analysis occurred during the unusual post-pandemic recovery. As a result, the relationships may not apply during standard recoveries or periods of slow growth. For example, the strong demand for government bonds by domestic nonbanks (which largely absorbed the reduction in central bank holdings), may have stemmed from the large post-covid stimulus (and not be available in the future) or from changes in other market prices. Second, although this paper has the important benefit of drawing from the experience of seven central banks pursuing QT, the number of observations for much of the analysis is still limited (particularly for announcement effects) and there is substantial heterogeneity across country experiences. The impact of QT could meaningfully vary based on the structure of a country's financial system and other economic characteristics.

Third, our estimates of the announcement and implementation effects of QT could understate any impact if markets incorporated these changes before the narrow dates used for our analysis, or if the effects take longer to play out than the short windows used for estimation. For example, if investors expected QT before our announcement dates, or if there are cumulative effects of implementing QT on the yield curve (both of which are likely), we could be meaningfully underestimating the impact of QT announcements and implementation on yields, respectively. Fourth, our analysis does not control for changes in the supply of government debt, including changes in the duration of issuance or the outstanding stock that occurred at the same time as QT. Fiscal authorities may have adjusted the timing and duration of new issuance to reflect changes in outstanding debt stocks as balance sheets were unwound, possibly muting the effects of QT (especially if this was expected). Finally, although QT has only had small effects (or no effects) on the variables analyzed in this paper, this may not apply in the future. As central bank balance sheets shrink, the relatively smooth adjustment to date could suddenly generate sharper movements in financial markets—as occurred in the US in 2019. It is impossible to estimate with any precision what level of reserves would correspond to such a "tipping point", especially as that level could vary based on other economic developments.[14]

[14] See Vissing-Jorgensen (2023).

With these important caveats, the analysis in this paper should give central banks more confidence to unwind asset purchases in the future—or at least more confidence than in 2021 when there had only been one prior experience with QT leading to a meaningful reduction in a central bank's securities holdings. All in all, while the effects of QT appear to be more than the "paint drying" hoped for in Yellen (2017), the effects to date have also been muted and much smaller than the effects of the QE programs launched during periods of market stress (with the opposite sign). In fact, the small effects of QT documented in this paper — such as a modest increase in government bond yields at the medium- and long-term horizon upon QT announcements, gradual rise in overnight funding spreads, and modest reduction in the convenience yield of government bonds — is a healthy part of the adjustment process of tightening financial conditions. Moreover, as some of the impact of QT appears to work through signaling tighter monetary policy, the discussion and guidance around QT could also be important in determining its effects. The challenge will be assessing when this smooth adjustment to date could suddenly transition to a liquidity crunch and have a sharper impact on financial markets—similar to that moment when water suddenly boils.

2. What Happened?: Strategies for QT and the Evolution of Central Bank Balance Sheets

This section provides background on: (a) the expansion of central bank balance sheets in response to the pandemic; (b) the rapid start to QT programs and different strategies followed by central banks for unwinding their securities holdings; (c) differences in how QT programs were communicated; (d) and projections of how central bank balance sheets will evolve over the next two years if programs are continued according to current parameters.

2.A. Quantitative Easing and "Peak" Balance Sheets

As Covid-19 evolved into a global pandemic, financial markets froze up, and economic activity collapsed, central banks adopted a range of policies to stabilize financial markets and support their economies.[15] This included reducing policy interest rates (if not already at their lower bounds), implementing a range of liquidity and credit support programs, and easing regulatory requirements. In many economies (and most advanced economies), a central part of this response was large asset purchase programs by central banks; in some countries this meant launching new programs, and in others it meant expanding earlier programs in terms of the size, speed and type of assets purchased. For most central banks, the vast majority of the securities purchased were government bonds, but many supplemented this with other types of securities, such as agency/mortgage/asset-backed bonds (e.g., the BoC, ECB and Fed), corporate bonds (e.g., the BoC, ECB, Riksbank, and BoE), state/provincial/territory/municipal/local debt (e.g., the RBA, BoC, RBNZ, and Riksbank). Appendix A1 provides information on this data and Appendix A2 on the resulting size and composition of the central banks' securities holdings for the seven

[15] See English, Forbes and Ubide (2021) for details on central banks' responses to the Covid pandemic.

economies that are the focus of this paper.[16] It also includes comparable information on the Fed's balance sheet in 2017-2019—the additional QT experience we include in this analysis—as it was the only central bank that implemented QT on a meaningful scale in the late 2010s.[17]

These large asset-purchase programs launched in response to the pandemic, especially when combined with earlier QE programs in response to the 2008 Global Financial Crisis and subsequent decade of slow growth and sub-target inflation, left central banks with large balance sheets. Figure 2.1 shows the surge in central bank holdings of all securities and just government securities relative to GDP (panels A and B, respectively) in response to the 2020 pandemic, as well as government securities relative to the government security market (panel C)[18]. While each of these central banks saw a meaningful expansion in their balance sheets, there are notable differences in the size of their (scaled) holdings at their peaks; for example, the BoE, ECB and Fed had much larger securities holdings (including all agencies, corporates, sub-national bonds, etc.) relative to GDP in 2021 than the other central banks in the sample.[19] Focusing only on government securities, however, the BoE had the largest holdings relative to GDP (37%), more than double the comparable ratios for the RBA, BoC, RBNZ and Riksbank (ranging from 8%-16%). Some of these central banks with smaller holdings relative to GDP, however, still owned a relatively large share of the government securities market. For example, RBNZ holdings peaked at about 40% of their government bond market—well above the US peak of about 28%.

Panels D through F of Figure 2.1 report comparable measures for the Fed during its QE and QT programs from 2008-2019 (hereafter referred to as the "pre-pandemic" episode). Even though the Fed's pandemic QE programs were much larger in size and scope than in the pre-pandemic episode, the differences relative to the size of the economy and government bond market were smaller due to interim growth in the US economy and bond market. More specifically, while total assets purchased in response to the pandemic were roughly double that before the pandemic (in terms of the nominal value), aggregate Fed holdings relative to GDP peaked at 34% after the pandemic, as compared to 24% of GDP in the pre-pandemic period.

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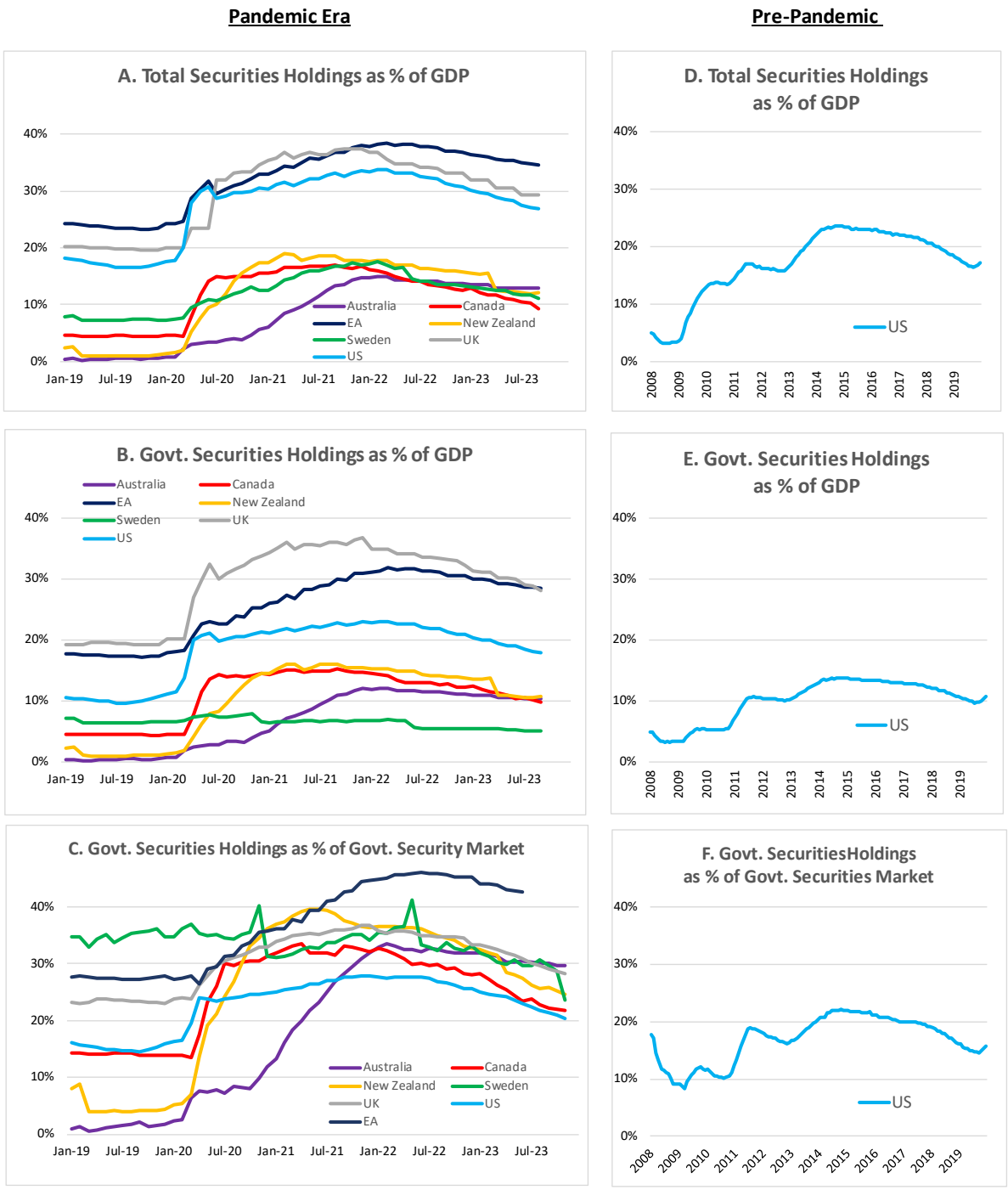
[16] These seven economies were selected based on three criteria: (1) advanced economies with sufficient market data for the empirical analysis; (2) adopted some type of asset purchase program in response to the pandemic; and (3) started some type of QT. Denmark, Norway and Switzerland did not adopt QE; Switzerland's asset purchases were in the form of FX interventions. Japan implemented a large QE program, but has not announced plans for QT.

[17] The ECB reduced its balance sheet from 2012 – 2014, when long-term refinancing operations (LTROs) expired and the Riksbank announced the start of QT in April 2019. We do not include either episode in this section.

[18] Central bank securities holdings generally only include local currency denominated securities and exclude securities held as foreign exchange reserves. They generally do not include securities held as collateral for repo lending nor adjustments to other lending and liquidity support programs, such as the ECB's TLTROs, the BoE's TFSME, and other programs aimed at supporting bank lending or involving direct lending by the central bank in response to the pandemic. More detail on the securities holdings can be found in Appendices A1 and A2.

[19] Comparisons of aggregate securities holdings across central banks is not straightforward as central banks have different methods of reporting their holdings of different types of securities and exposure to credit and lending programs. See Appendix 1 for details on the sources, definitions and calculations used in this paper. The statistics in this paragraph reflect data from Haver and central bank websites.

Figure 2.1
Central Bank Securities Holdings During QT



Notes: Reports central bank holdings of all securities, or government securities, scaled by either GDP or the total government securities market. Central bank holdings are all securities holdings reported by the central bank at the end of each month and include securities that may not have been part of a QE program. The government securities market includes central bank holdings and all outstanding marketable bills, bonds, and other securities (including various indexed and inflation-linked securities).

Source: Data on aggregate securities holdings, GDP and government securities market from Haver. Data on government securities holdings from Central Bank websites and Haver. See Appendix A1 for details on data sources and definitions by country.

2.B. Quantitative Tightening Begins Sooner and Faster

While central banks hoped to be able to unwind at least a portion of their pandemic-related asset purchases at some point, this was generally expected to occur late in the process of monetary policy normalization, and well after the recovery was entrenched. According to the standard "central bank playbook", a central bank should first end any asset purchase programs, then raise the policy interest rate in a way that supported a sustainable recovery and price stability, then continue to raise the policy interest rate until it had reached a level that provided some cushion to respond to future shocks, and only then, assuming the recovery was still on track, begin QT. QT would begin with the passive roll-off of securities as they expired (possibly subject to caps or limits so that this occurred at a gradual pace), with the option to move to active sales if faster balance sheet reduction was desired. Given the slow and tepid recoveries after recent recessions, most analysts expected this normalization process would be slow—implying any reduction in balance sheets would not occur for years, and even then only at a gradual pace.

This expectation that QT would not begin for an extended period was supported by the US experience with balance sheet reduction in 2017—the primary example from before 2020 that central banks saw as relevant for unwinding balance sheets after the pandemic. During this earlier tightening cycle, the Fed ended QE in October 2014, raised interest rates for the first time in December 2015, and only began QT in October 2017—three years after ending asset purchases and almost two years after "liftoff" (i.e., the first rate hike of the cycle). Moreover, this QT program was phased out earlier than expected, leaving a larger terminal balance sheet than forecast at the start of QT (as well as at the start of QE). As this was the only recent experience with QT, it is not surprising that central banks were not even discussing QT as economic activity bounced back in late 2020 and early 2021.[20]

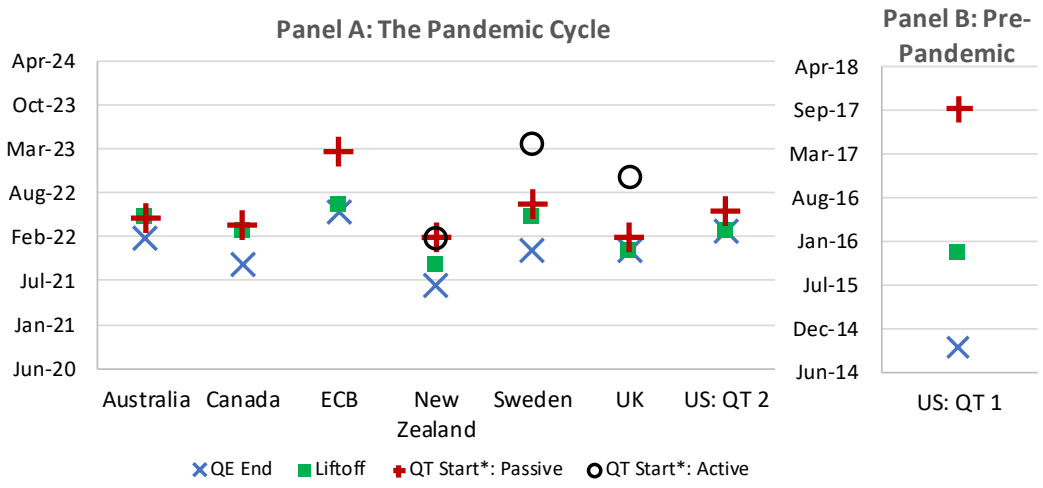
The post-pandemic recovery, however, was different. Not only did economic activity rebound faster than forecast, but inflation jumped well above targets. Central banks could begin the process of monetary policy normalization much sooner than expected, tighten by larger increments, and accelerate the "playbook" timeline, thereby moving forward the start date for QT. The US experience captures this shift in the speed of monetary policy normalization. At the start of 2021, the Fed was not expected to liftoff until well into 2024, and then not to begin QT until 2024 at the earliest.[21] QE was completed in March 2022, and in the same month the Fed raised interest rates for the first time and simultaneously announced that a reduction in its balance sheet would begin "at a coming meeting"[22]. On May 4, 2022 the Fed announced that

[20] The prominent exception was Andrew Bailey, Governor of the Bank of England, who discussed using the central bank's balance sheet as a policy tool in a discussion at the Jackson Hole Symposium in August 2020. Link.
[21] The results of the January 2021 Survey of Primary Dealers from the Federal Reserve Bank of New York did not have QT beginning before Q4 2023, the latest quarter included in the response. The Survey of Market Participants for that month had a similar response. See here and here.
[22] See press release at: Federal Reserve Board - Federal Reserve issues FOMC statement.

QT would begin on June 1, 2022.[23] In summary, the lag from ending QE to starting QT had been compressed from 36 months in the pre-pandemic cycle to 3 months, and the lag from "liftoff" to QT was abbreviated from 22 months to only 3 months.

This accelerated pace of monetary policy normalization after the pandemic, including the earlier start to QT, was even more pronounced in countries other than the US. Figure 2.2 shows the timetable for the seven economies in our sample after the pandemic: the end date of QE (in blue), liftoff (in green), and the start of QT (in red for passive QT and yellow for the start of active sales, if relevant). Panel B shows the longer timeline for the US in the pre-pandemic period, with QT1 denoting US QT from 2017-2019 and QT2 the more recent period.[24] Panel A shows that this tightening cycle was so compressed in many countries that they often moved several steps in subsequent meetings—or even at the same time. For example, the BoE both ended QE and raised rates for the first time in December 2021, and then started QT at its next meeting in February 2022. The RBA ended QE in February 2022, and then simultaneously raised rates and announced the start of QT at its May 2022 meeting. The RBNZ announced the start of both passive QT and active asset sales at the same time in February 2022, just seven months after it ended its asset purchase program. In the post-pandemic period, QT started just 7 months (on average) after the end of QE and 3 months (on average) after liftoff—much faster than the comparable 36 and 22 months for the US during its last tightening cycle.

Figure 2.2
Key Dates in the Monetary Policy Playbook: QE, Liftoff and QT



Notes:Dates are when central banks announced the end to QE, liftoff (the first hike in the policy interest rate), or start of QT (either passive or active). The QT dates refer to news on government securities holdings and do not include QT announcements for other types of assets (such as corporate bonds). The announcement dates may not capture any changes in central bank balance sheets that are not part of QT. See Appendix A2 for details and sources.

[23] For details on the May 2022 QT announcement, see Federal Reserve Board - Plans for Reducing the Size of the Federal Reserve's Balance Sheet. For more details on announcements related to QT, see Appendix A2.
[24] In Sweden, the other example of pre-pandemic QT, the transition from QE to QT was faster than in the US but slower than in most economies during the post-pandemic transition. More specifically, the Riksbank ended QE in December 2017, lifted off in December 2018, and announced the start of passive QT in April 2019.

This much faster adoption of QT reflected the strong post-pandemic recovery, combined with a rapid acceleration in inflation. Central banks could still follow the stages in their standard "playbook", but given the degree of monetary tightening that was required, they also had the luxury of not worrying if reducing balance sheets would constrain their ability to raise rates to levels that would provide sufficient cushion in the future. Central banks had a lot of ground to cover to bring inflation down to targets. In fact, if QT meaningfully raised interest rates over medium- and long-term horizons, and thereby tightened financial conditions, it could even put less onus on adjustments in short-term rates and thereby reduce risks around a rapid and unexpected increase in short-term borrowing costs.[25] Also, in some countries where there were political concerns about the expansion of central bank balance sheets and their intervention in securities markets, beginning to reduce balance sheets could reinforce central bank claims that QE programs were a temporary, emergency response and not a standard intervention or tool for financing government budget deficits.

While all the central banks included in this analysis began QT sooner than was expected in 2020, different central banks adopted different approaches for reducing their balance sheets. Most central banks began with "passive" QT, i.e., allowing securities to expire and not purchasing new securities in order to keep the size of the balance sheet constant (referred to as "roll-off"). Three central banks have also started active sales (the RBNZ, Riksbank and BoE). When central banks began passive QT, most allowed all expiring assets to roll-off (such as the BoE and BoC), even though this led to "chunky" adjustments in the balance sheet when holdings were concentrated in securities of the same duration.[26] In contrast, the Fed, and initially the Riksbank, adopted "partial passive" QT, with caps on the maximum amount of securities that would roll off in a given period in order to slow the pace of QT and smooth the adjustment.

Most central banks prioritized unwinding holdings of government securities, although some are also unwinding other types of securities. For example, the Fed began passive QT of agency MBS debt at the same time it began QT for government debt. The BoE started active sales of corporate bonds before government bonds, so that it had unwound almost all of its corporate bond holdings by August 2023. The Riksbank is currently unwinding its holdings of both government and non-government bonds, but only pursuing active sales for government bonds.

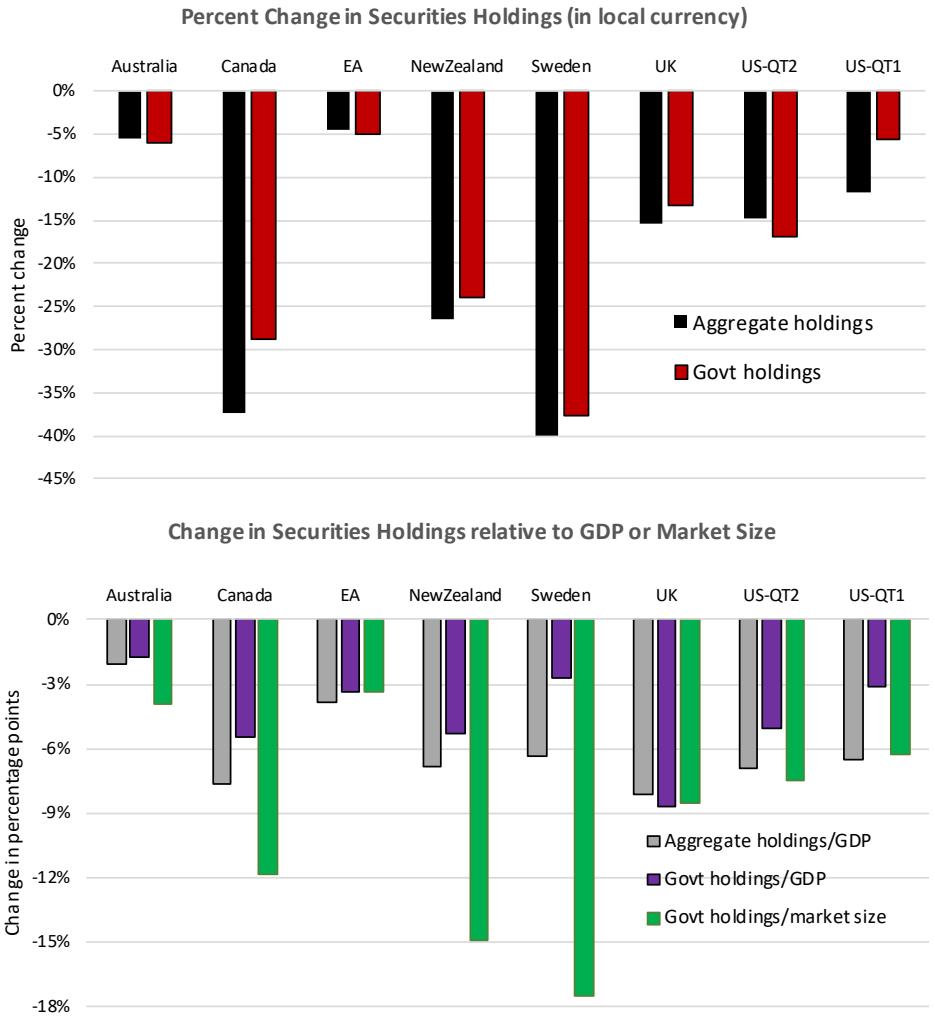
These QT programs have led to meaningful reductions in central bank balance sheets. The top of Figure 2.3 shows the percent change in aggregate and government securities holdings for each of the countries in the sample from their post-pandemic peak through end-2023 (or the latest data available as of Dec 25, 2023). The bottom panel shows the percentage point change when the holdings are scaled by GDP or the relevant market. The comparable statistics are shown on the right for the Fed's QT in the pre-pandemic period (from 2017-2019). The Riksbank and BoC have accomplished the largest percent reductions in their (unscaled) securities holdings—shrinking their aggregate holdings by 40% and 37% respectively, and government

[25] See discussion in Forbes (2021).

[26] For example, in the UK about £15bn and £20bn of gilts held by the BoE expired in July and September 2023, respectively, but no gilts rolled off the rest of the year.

holdings by 38% and 29%, respectively. The RBNZ is not far behind, shrinking its aggregate and government holdings by 26% and 24%. These reductions are also meaningfully larger than for other central banks when scaled by their relevant securities markets, but more in line with progress elsewhere when assessed relative to annual GDP. The rapid rate of QT in Canada is particularly noteworthy, as the BoC is not selling securities (in contrast to active QT by the RBNZ and Riksbank). The relatively fast reduction in the BoC's balance sheet through just passive QT reflects the shorter duration of its holdings.

Figure 2.3
QT from Peak Balance Sheet through Dec. 2023



Notes: Top panel shows percent change in central bank holdings of aggregate securities or government securities, based on prices in local currency. Bottom panel shows the percentage point change in the same holdings relative to GDP or the total government securities market (including central bank holdings). See Figure 2.1 for more details. QT is calculated as the percent change or change from the "peak" (i.e., largest value for the relative statistic) through Dec 2023 (and through Nov 2023 for New Zealand). The exception is US-QT-1, which is the change/percent change from the pre-pandemic peak in the mid-2010s through end-2019.
Source: Based on data is from Haver and central bank balance sheets. See Appendix A1 for details.

2.C. Communicating Quantitative Tightening

Central banks have not only adopted different strategies for implementing QT, but also followed different strategies for communicating about when QT would start and how it would be adjusted. Appendix A2 provides a detailed timeline of key communications related to QT for each of the seven central banks in our sample (with the US divided into sections for its pre-pandemic and post-pandemic phases).

Some central banks provided basically no information about when, how, or under what conditions QT would begin. For example, the Riksbank had no formal communication about QT before its April 2022 meeting announcing that QT would begin in July, and the RBNZ surprised markets in its February 2022 meeting with an announcement that QT would begin in July and include not only passive balance sheet runoff, but also active sales.

Other central banks discussed QT well in advance, however, through speeches and other central bank communications, including the Minutes of monetary policy meetings as well as special statements about how any balance-sheet reduction would occur. For example, at the BoC, the Governor and then Deputy Governor gave speeches providing key information about how QT would likely proceed, followed by an announcement of the start of QT at the next policy meeting. The Fed had much more extensive pre-communication about QT (in both 2014 as well as 2021/22), providing a drip-feed of information released gradually over several months in press conferences and Minutes. The Fed also provided formal statements at key dates on how QT would occur, such as a very general "Principles for Reducing the Size of the Federal Reserve's Balance Sheet" in January 2022 and then more details in "Plans for Reducing the Size of the Federal Reserve's Balance Sheet" in May 2022.[27] This more gradual communication by the Fed in building up to starting QT was logical as a surprise in US monetary policy is more likely to have global ramifications and the Fed sought to avoid another "taper tantrum".

The BoE followed a different strategy than other central banks, providing guidance on specific conditions to either trigger the start of QT or the start of discussions about QT. More specifically, in August 2021 the BoE confirmed that passive QT would begin when the policy interest rate reached 0.5%, and active sales would be considered when the policy rate reached 1%.[28] This announcement updated guidance from the 2010s, but reduced the policy interest rate that would trigger QT (previously set at 1.5%). Lowering the threshold to start QT was motivated, at least partly, by concerns about a "ratchet effect", i.e., that if central banks bought assets during easing cycles, but did not unwind them during tightening cycles, balance sheets would continually grow and thereby limit the ability to use this tool in the future[29]. The BoE had not started QT during its previous tightening cycle (as interest rates had peaked at only 0.75%), so lowering the threshold to begin QT would make it more likely the BoE could begin unwinding its

[27] Link to the Jan 2022 statement and link to the May 2022 statement

[28] In both cases, there was the option to delay QT if not "appropriate given the economic circumstances". This opt-out was utilized during the gilt-market crisis in the fall of 2022. For the full statement, see Bank of England Monetary Policy Report, August 2021.

[29] See Bailey et al. (2020).

holdings during the post-pandemic cycle. This adjustment in messaging was propitious. As central banks began to pivot toward tightening monetary policy in late 2021 and early 2022, it was easier for the BoE to transition to QT without surprising markets. Investors began to automatically price in this adjustment in balance sheet policy as stronger economic data caused them to move forward their expectations for UK rate hikes.

2.D. What Comes Next? When will QT Programs be Done?

Despite the meaningful reduction in securities holdings shown in Figure 2.3, central banks still hold significantly more assets than before the pandemic. Central banks would like to further shrink their balance sheets, but there is substantial uncertainty about when to end this process and the optimal size of balance sheets and reserve holdings in the future. Most central banks are planning to continue QT "in the background" and according to current program parameters. For example, the BoE plans to review its QT program annually, at which point it would consider adjusting program parameters. Policy interest rates will continue to be the main monetary policy tool, except in periods of market disruption or illiquidity, in which case any ongoing QT could be halted or delayed.

Most central banks have provided little guidance on when QT will end. The hope is that careful monitoring of market conditions will provide information on when they are nearing optimal reserve levels, at which point they could slow, and then stop, ongoing QT. The BoC has provided the clearest guidance on the parameters that will determine when the program will wind down—when settlement balances have reached a range of C$20bn – C$60bn (about 1%-2% of GDP), which "will likely occur sometime around the end of 2024 or the first half of 2025."[30] After reaching this target, the BoC will start buying assets again as part of regular balance sheet management. In the US, some Fed officials, such as Governor Waller, have laid out heuristics based on reserves relative to GDP for how QT could conclude.[31] More recently, Dallas Fed President Logan suggested that the Fed should slow its pace of QT as the ON RRP facility reaches low levels to "help get to a more efficient balance sheet in the long run by smoothing redistribution and reducing the likelihood that we'd have to stop prematurely." [32]

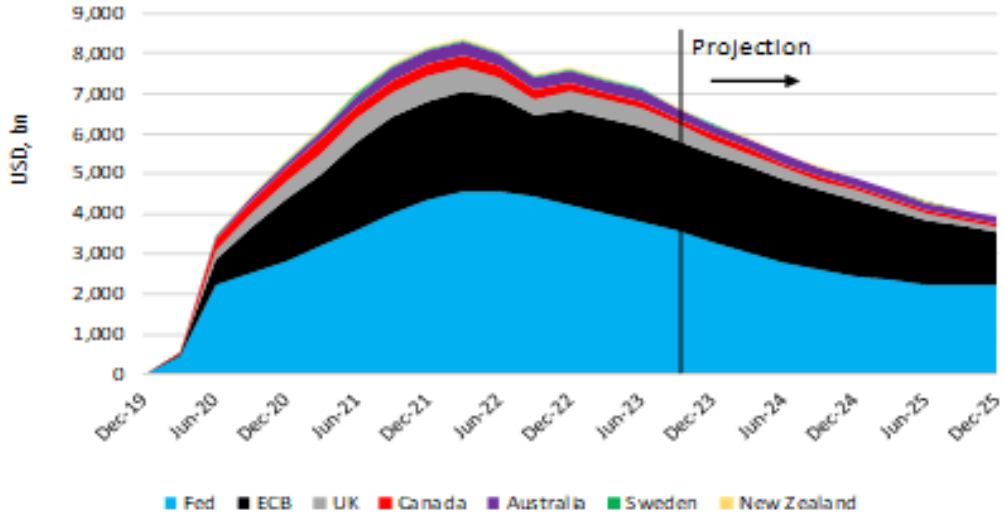
When will central banks likely complete their QT programs? This is difficult to assess for several reasons. There are wide uncertainty bands about the optimal size of central bank balance sheets, especially with new facilities that should provide liquidity and reduce the demand for central bank reserves (such as the Fed's Standing Repurchase Facility, or SRF).[33] The optimal

[30] See speech by Deputy Governor Gravelle, March 29, 2023.
[31] Waller's previous comments indicated that the pace of QT could slow when reserves hit 10% to 11% of GDP and that QT could cease when this ratio reaches approximately 9%. See Reuters reporting here. These assumptions were also used in the 2022 Open Markets Operations report from the Federal Reserve Bank of New York. More recent comments from Waller suggested the Fed could slow earlier than these heuristics suggest. See a recent Brookings report from David Wessel here.
[32] 01/06/24 comments at the annual American Economic Association meetings, available here.
[33] The Fed established the SRF in July 2021 to offer overnight repos to primary dealers (and later some banks) to allow counterparties to obtain funds against Treasuries, agency debt and mortgage-backed securities.

level of reserves will also depend on a range of market and regulatory conditions, which are difficult to predict. Also, the continuation of QT could be impacted by material changes in the macroeconomic environment. For example, QT could be slowed or stopped if central banks begin to reduce policy rates to provide accommodation in response to slowing growth.

Despite these challenges related to estimating the optimal level of reserves, it is still useful to project how QT programs could evolve. In order to make these projections, we make several simplifying assumptions. Specifically, we limit our projections to extend through end-2025 and assume that central banks continue their QT programs according to existing parameters.[34] To avoid having to predict the future evolution of GDP or debt securities outstanding, we also only project the level of central bank balance sheets. These assumptions may not hold ex-post, as central banks will likely slow the pace of QT when they believe they are nearing the level of optimal reserves, and changes in market or economic conditions could cause central banks to adjust the pace of QT well before the end of 2025. Nonetheless, these estimates provide a useful baseline for the evolution of individual central bank balance sheets if there is no change in current QT programs.

Figure 2.4
Combined Central Bank Balance Sheet Projections
(Net Increase from end-2019)



Notes: Chart shows combined central bank balance sheet projections through end-2025 under the assumption that QT proceeds under its current parameters. All holdings are converted to USD using exchange rates from November 2023.

[34] More specifically, passive roll-off is assumed to continue according to current parameters—such as full expiration for the BoC, or subject to current caps for the Fed. Active sales are assumed to continue at the latest annual rate for central banks that have specified a fixed amount (such as the Riksbank). For countries that combine active and passive QT to accomplish a fixed reduction in the balance sheet each year (such as the BoE), we assume the latest announced amount is continued.

Figure 2.4 shows the simulated reduction in aggregate central bank holdings of government securities over time.[35] To perform this calculation, we translate each central bank's securities holdings into US dollars by fixing the bilateral exchange rates at the November 2023 average level. Securities holdings for these seven central banks fell by nearly $2.2tn through end-2023 from the peak of more than $8tn in mid-2022. Through end-2025, we project a further $2.2tn reduction in the balance sheets for these central banks. Despite this progress, the aggregate securities holdings for these central banks will remain about $4tn above pre-covid levels at end-2025 (and likely higher if central banks slow the pace of asset reduction relative to these simulations, as recently suggested by Fed officials). Not surprisingly, the aggregate reduction in global central bank balance sheets is driven by the reduction in the largest economies—particularly the US and Euro area —even if the relative pace of QT in these large economies is somewhat slower. Appendix Figure A2.1 shows the underlying, individual local currency projections for the balance sheets of each of our seven economies of interest.

3. The Impact of QT Announcements

This section evaluates if QT announcements affect government bond yields and other financial measures in our sample of seven advanced economies. To the best of our knowledge, this is the first cross-country analysis of the impact of QT—an analysis not previously possible given the limited experience reducing central bank balance sheets before 2022. This section is divided into six parts. Part A briefly reviews related literature and part B compiles and categorizes the QT events that will be the focus of the analysis. Part C develops the event-study methodology, including a discussion of its strengths and weaknesses. Part D reports baseline estimates of the impact of different types of QT events on government bond yields and other financial market variables for the panel as well as individual economies. Part E explores the channels by which QT affects government bond yields, including through signaling, portfolio rebalancing and duration effects, as well as through spillovers on other economies. The section ends with a summary of the key results, including a comparison to the estimated effects of QE in earlier research. Additional sensitivity tests are summarized in Appendix A.3.

3.A. Related Literature

The analysis in Section 3 builds on three related bodies of research: event studies assessing the impact of QE announcements, analysis of the channels by which QE affects the economy, and a small number of papers analyzing the impact of US QT from 2017-2019.

A number of papers use a standard event-study methodology to assess the impact of QE news on bond yields and other financial variables, a literature well summarized in Borio and Zabai

[35] These simulations are based on total central bank holdings—including the PEPP for the ECB. As a result, there are some differences between these statistics and those in Figures 2.1 and 2.3, which focus on a narrower set of holdings (only securities specifically purchased as part of QE programs).

(2016), Gagnon (2016) and Greenlaw et al. (2018).[36] These studies focus on the impact of QE announcements—consistent with market prices being forward looking —rather than when asset purchases occur (the focus of Section 4). These papers generally conclude that large-scale asset purchases lead to a meaningful easing in financial conditions, including a decrease in yields on government bonds (and mortgage-backed securities in the US), an increase in equity prices, and depreciation of the exchange rate. Estimates of the size of these effects vary meaningfully across episodes and studies, typically with larger effects during periods of heightened financial stress and reduced liquidity. After surveying this literature, several studies provide benchmarks of the effects of QE. For example, Borio and Zabai (2016) concludes: "the cumulative impact of the Fed programs on 10-year government bond yields may have been of the order of over -100 basis points." Gagnon and Sack (2018) concludes that for the US, "a purchase of long-term bonds equivalent to 1.5 percent of GDP has a stimulative effect roughly equal to a cut in the policy rate of 0.25 percentage point." Greenlaw et al. (2018), however, argues that these estimates are overstated as the event studies do not control for other news affecting financial variables on key event dates. A challenge in all of these studies is that much of the impact of QE may have been priced in before official announcements, making it difficult to identify the "surprise" component needed for an event study (D'Amico and Seida, 2020).

A number of these event studies, as well as papers using other approaches (such as affine term-structure models or VARs) attempt to understand the channels by which QE affects the economy. Most of these papers find evidence supporting a strong signaling effect, i.e., that QE brings down expectations for policy interest rates in the future (Krishnamurthy and Vissing-Jorgensen, 2011; Bauer and Rudebusch, 2014; and Bhattarai et al., 2015). Other papers, however, argue that QE worked more through portfolio rebalancing and duration effects, i.e., by transferring longer duration assets onto the central banks' balance sheet and thereby increasing demand for other duration assets held by the private sector and lowering risk premia (Gagnon et al., 2011; Vayanos and Vila, 2021; D'Amico et al., 2012; Carpenter et al., 2013; Ihrig et al., 2018; and Selgrad, 2023). Another series of papers argues that QE primarily works by improving liquidity and market functioning, supported by evidence that QE has greater effects when markets are stressed and illiquid (Vissing-Jorgensen, 2021). Logan (2024b) discusses each of these channels.

Analysis of the impact of QT has been much more limited and focused on the US experience in 2017-2019. Smith and Valcarcel (2023) is the first analysis (to our knowledge) of this episode, and this event study finds no significant effect of US QT announcements on yields and other financial market variables (and only small effects from tapering announcements). In another section of this paper, however, a VAR analysis of the Fed's balance sheet finds evidence of liquidity effects that tightened financial conditions through a range of measures (including on short-term rates, the exchange rate, and yields on Treasuries, mortgage securities and corporate bonds). Ludvigson (2023) also uses an event-study approach to analyze US QT announcements and finds larger effects—particularly for the stock market and longer-horizon federal funds

[36] Prominent examples of event studies assessing the impact of QE include: Krishnamurthy and Vissing-Jorgensen (2011), Gagnon et al. (2011), Joyce et al. (2011), Swanson (2011) and Neely (2015).

futures rates. This analysis then uses a mixed-frequency, macro-finance model combined with structural estimation to understand the drivers of these effects. Although the factors vary significantly across events, US QT announcements often correspond to changes in the equity return premium, with little effect on expected inflation or real GDP growth, suggesting that most of the impact of QT announcements is on financial markets.

This body of research has several implications for the following analysis of QT announcements. If QT is simply "QE in reverse", then it could involve a meaningful increase in bond yields and tightening in other measures of financial conditions. If QT works primarily through a signaling channel, i.e., by implying greater central bank commitment to raising policy interest rates, it should correspond to an increase in expectations for short-term policy rates. If QT works primarily through a portfolio balancing channel, it would imply an increase in longer-term yields, a decline in the prices of duration assets (such as equities and corporate bonds), and an increase in the term premium. On the other hand, QT could have minimal effect and be more "like watching paint dry", as suggested in Yellen (2017). If central banks were able to separate QT from decisions on the policy interest rate, then QT announcements might not provide any signaling effect, More specifically, if QT occurs in a period of ample liquidity and low risk premia, it might not have any portfolio-balancing effect or liquidity effects. The only way to differentiate between these possibilities is additional empirical analysis.

3.B. The QT Events and Classifications

To assess the impact of QT, we begin by compiling a list of key news and announcements related to QT in the seven advanced economies that are the focus of this paper (Australia, Canada, Euro Area, New Zealand, Sweden, UK and US). We include formal central bank announcements at policy meetings, press conferences, or in other releases on the broad strategy for QT as well as on specific parameters for a QT program (such as quantities, caps, or start dates). We also include speeches by senior central bank officials that provide meaningful new information on the strategy, timing or parameters of QT. We do not include speeches or communication that simply repeat former guidance if there is no new information or that only include information on a very small subset of asset holdings. We compile this list of QT related news by reviewing central bank communications from Jan. 2021 through Oct. 2023 (including Minutes, speeches, and other announcements), reviewing analyst reports from the financial sector, and reviewing recent academic papers on US QT (Smith and Valcarcel, 2023; Ludvigson, 2023). We also review the same material for the US from 2014-2019 and Sweden in 2019. We do not include discussions related to tapering asset purchases (unless this includes a discussion related to QT).

Appendix A2 lists the resulting timeline of 48 QT events for the seven economies in our sample and the corresponding dates used in the analysis below. Each QT event is also categorized based on three criteria: (1) the type of news; (2) the form of the transaction; and (3) the securities involved.

First, we categorize each event into the type of news:

- ***Preliminary Discussions (PD):*** broad discussions laying the groundwork for QT and general principles for QT when it occurs, without any specific dates or quantities.

- ***Main Announcements (MA)*****:** concrete announcements on how QT is likely to proceed, including magnitudes and dates (even if all details or a concrete start date are not provided) or announcements with details on how QT will be implemented;[37]

- ***Wind Down (WD):*** announcements on the slowing or ending of a QT program, including announcements of broad principles as well as details on how any reduction in the pace of QT would proceed.

As discussed in Section 2.D on central bank communications around QT, some central banks provided extensive communication on the general principles and approach to QT over a number of months before announcing concrete plans for balance sheet reduction (such as the US). Others started QT with little preliminary discussion (such as New Zealand). Of the 48 QT events in the sample, 15 are classified as *Preliminary Discussions,* 28 are *Main Announcements* and 5 are *Wind Down.*

Second, each event is also classified by the form of the QT transaction.[38] The transaction is either ***Active*** (sales of central bank securities holdings) or ***Passive*** (allowing central bank securities to roll-off the balance sheet when they expire, sometimes subject to caps or limits). All countries in the sample have started *Passive* QT, while New Zealand, Sweden and the UK have also started *Active* QT. Of the 48 QT events in the sample, 19 involve news on *Active* QT and 32 involve news on *Passive* QT (with 3 events including news on both).[39]

[37] We also divided these *Main Announcements* into two subgroups: the initial announcements of QT programs and "*Extra Information",* i.e., additional information on the program, such as market announcements with details on how the QT program would be implemented or announcements confirming news that was previously floated (often in speeches). There are only six *Extra Information* events, however, and treating them as a separate category does not impact the main results below.

[38] When there is news on different types of bonds, the information is classified according to the information for the largest category—government bonds. For example, if there is an announcement of passive QT for government bonds and active QT for corporate bonds on the same day, the announcement is classified as an event with information on passive QT for government bonds. In most cases, announcements for different types of bonds are for the same type of policy (such as in the US, where news on QT for government and agency bonds often occurred on the same date and with the same types of transactions, albeit different magnitudes). The main examples of QT announcements differing across asset types occurs in the UK, where actives sales of corporate bonds occurred before active sales of gilts.

[39] A majority of the events involving active QT are in the UK, and many involve updates or changes to plans for the sales of government and/or corporate bonds around the LDI crisis in the fall of 2022. As discussed below, the baseline analysis excludes events during periods of substantial market turmoil (such as around the LDI crisis and banking turmoil in SVB/First Republic/Credit Suisse in March 2023).

Finally, each QT event is also classified by the securities involved in the transaction. The four security categories are: ***Government bonds*** (G), ***Corporate bonds*** *(C)*, ***Agency/Mortgage-backed bonds*** *(A)*, and ***State/Municipal/Territory/Local bonds*** *(S)*.[40] All central banks in the sample have started QT for government bonds. The ECB and BoE have also started QT for corporate bonds, and the ECB and Fed for agency/mortgage-backed bonds. The RBA, RBNZ, and Riksbank have started QT for state, municipal, territory or local bonds (with more information on the specific holdings in Appendix A3). Of the 48 QT events in the sample, 43 involve some type of news related to *Government* bonds, while 12 include news on *Corporate* bonds, 19 on *Agency* bonds and 5 on either *State, Municipal, Territory or Local* bonds.

3.C. The Event Study Methodology

To assess the impact of QT announcements, we build on the standard event-study methodology widely used to assess the impact of QE or QT1 (i.e., 2017-2019) in the US (e.g., Gagnon et al., 2011; Krishnamurthy and Vissing-Jorgenson, 2011; Smith and Valcarcel, 2023). This framework focuses on the change in financial market variables over the two days corresponding to QT announcements. We adapt this framework to incorporate the cross-country variation in our data and other news relevant to monetary policy. We also adapt the framework to be able to assess the impact of different types of QT announcements (based on the type of news, transaction, security, and country).

More specifically, our baseline analysis estimates the effects of different categories (*C*) of QT events and each individual QT event using the following two equations:

$$\Delta y_{it} = \alpha_i + \textstyle\sum_C \beta^C QT_{it}^C + \boldsymbol{\gamma News}_{it} + \varepsilon_{it} \qquad c = 1, \dots, C \tag{3.1}$$

$$\Delta y_{it} = \alpha_i + \textstyle\sum_N \beta^n QT_{it}^n + \boldsymbol{\gamma News}_{it} + \varepsilon_{it} \qquad n = 1, \dots, N \tag{3.2}$$

The Δy_{it} is the change or percent change in the relevant financial variable for country *i* over the two days from *t-1* (i.e., the closing price the day before the QT event) through *t+1* (i.e., the closing price the day after the QT event). The α_i is a country fixed effect. The QT_{it}^C is a dummy variable which takes a value of 1 if a QT event of category *C* occurs in country *i* on date *t*.[41] The N is a number for each QT event listed in Appendix A2, so that each event has a unique identifier, and QT_{it}^n is a dummy variable which takes a value of 1 if *QT* event *n* occurs in country *i* on date *t.* All regressions are estimated with robust, Newey-West standard errors.[42]

[40] If an announcement date includes news on QT for government bonds as well as other types of bonds, we classify the event based on the relevant news for government bonds, which represent the vast majority of holdings and QT for each country.

[41] The categories include a dummy for: (a) all QT events; (b) QT events classified by the type of news; (c) QT events classified by the type of transaction; (d) QT events classified by the type of security; or (e) QT events by country. We cannot control for all characteristics simultaneously due to the limited number of QT events.

[42] We use Newey-West standard errors with 5-day lags to adjust for any serial correlation, including that introduced by the two-day windows. In our baseline analysis, we also exclude the day before the QT announcement and the four days after in order to avoid treating any market news just before the announcement or any lagged effects as

We follow the standard practice in this literature of focusing on the financial market impact over a two-day window. This provides investors time to absorb and incorporate the news (especially as announcements can be followed by press conferences or interviews later in the day or the next day), and allows for prices to adjust in any markets that are less liquid.[43]

The vector $\boldsymbol{News_{it}}$ controls for other monetary policy and economic data news in country *i* at time *t* that could affect the financial variables on the left-hand side. Although this is often not included in event studies, it is important to control for any such news that is correlated with the QT announcements and affects market prices (i.e., omitted variables), as highlighted in Greenlaw et al. (2018). Ignoring any such news could bias estimates of the impact of QT. This is an important concern for our analysis as many of the QT events were announced by central banks as part of a regular policy meeting, and many of these meetings also included changes in the policy interest rate (usually an increase during the 2022-2023 window when most of the QT events in our sample occurred). If any changes in the policy interest rate were expected, this should already have been priced into markets and not affect the estimates, but if any change in the interest rate was a surprise, omitting this from the analysis could bias upward estimates of the relationship between QT announcements and yields (as well as affect estimates of the impact on other financial variables). In order to address this, our baseline adds controls for two variables: any surprise in the policy interest rate and other economic data news (not including news related to monetary policy announcements). We measure the surprise in the policy interest rate as the difference between the policy rate announced on that day relative to median expectations for the announced policy rate the day before the meeting.[44] We measure other economic data news as the change in the Citigroup Economic Surprise Index over the same two-day window as the left-hand side financial variable. In additional tests below, we also control for changes in forward guidance on short-term policy rates—but we do not include this in the main analysis as QT announcements could be part of such guidance.

For the baseline analysis, we focus on a subset of the QT events listed in Appendix A2 that involve government bonds, include news related to new/additional/incremental QT, and that

being a "non-event" day. These exclusion windows have no impact on key results. As discussed in the sensitivity analysis, we also estimate regressions without country fixed effects (with and without clustered errors by country) and using random effects. None of these variations has a meaningful impact on the key results. We do not control for time fixed effects in order to be able to estimate any spillovers from QT on other economies (Section 3.E).

[43] In sensitivity tests, we explore the impact of measuring the left-hand side variables over shorter (one-day) or longer (one- or four-week) windows. See the discussion in Appendix A.3. Key results are similar, but the magnitude of the estimated effects tends to be smaller in the shorter window, and larger in the longer windows. The standard errors are larger for the one-day and one-week estimates, such that many estimates become insignificant. Key results for yields are generally larger and highly significant over the four-week window, but this likely captures other changes in policy over the longer period.

[44] Measured by the median rate expected by market analysts, reported by Bloomberg. In sensitivity tests, we also measure the interest rate surprise as the difference between OIS expectations for the policy rate at the next meeting versus the announced rate, with key results unchanged.

occur when there was not extreme market volatility unrelated to QT.[45] More specifically, we exclude events classified as *Wind Down* (which would be expected to have the opposite effect of the majority of the announcements) and exclude several QT events in the UK that only include news relevant to corporate debt (which were a small share of asset holdings). Also, for our baseline, we focus on the sample period from January 1, 2014 through October 31, 2023[46] and exclude three windows of heightened market volatility unrelated to QT: the year 2020 (the start of the pandemic), the window around the UK's LDI crisis (defined as September 22 – October 15, 2022) [47], and the window around the SVB/Credit Suisse Banking turmoil (defined as March 8 – March 20, 2023)[48]. The resulting set of QT events for our baseline analysis includes the 39 dates marked with a "*" in Appendix A2.

The β^C coefficients in equation (3.1) are therefore the average effects of all QT events (or a category of QT events) across economies and over time, while the β^n coefficients in equation (3.2) are the effects of each individual QT event (i.e., for one country on one date). All estimates control for any surprise in the policy interest rate and other economic news over the same window.

In order for estimates of β^C and β^n to be unbiased, we need to make several assumptions.[49] First, the QT announcement is not affected by the 2-day change in market prices (Δy_{it}), i.e., reverse causality; this is a reasonable assumption as QT announcements are planned well in advance. Second, any variables correlated with the QT announcement and that affect market prices are included in the equation. Omitted variables that are a particular concern are any other changes in monetary policy or economic news that occur at the same time. To capture these potential omitted variables, we include the surprise component in any interest rate decision and a measure of other economic news around the time of QT announcements in the vector $\boldsymbol{News_{it}}$, but there could be other information that affects estimates. We explore the role of one potential omitted variable—forward guidance—in Part 3.E. below. Third, the QT announcement should not contain "information effects", i.e., private information by the central bank on the economic outlook; research by Bauer and Swanson (2023) suggests these effects are small for monetary policy announcements.

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[45] In the sensitivity analysis, we include a broader set of transactions (including *Wind Down* events or events that only include corporate bonds*),* as well as add the periods of market turmoil around the start of the pandemic, the LDI crisis and problems in SVB/Credit Suisse. None of these changes meaningfully affects the main results—although the results for *Wind Down* events are significantly different (as expected).

[46] We have repeated the analysis for only the post-Covid window (starting in 2021), or for all countries post-2021 plus the US from 2014-2019. Key results are unchanged. We end the sample at end-September 2023 as the last QT announcement in our sample is Sept. 21, 2023.

[47] The exclusion window for the LDI crisis is defined as starting on September 23, 2022, when the UK government announced its "mini-budget" that triggered a market sell-off. The window is defined as ending on October 14, 2022, when the BoE ended its emergency purchase program.

[48] This exclusion window is defined as starting on March 8, 2023, when SVB announced its large losses and plans to raise new capital, prompting a Moody's downgrade and subsequent collapse in SVB's stock price. On March 10 and March 11, SVB and Signature Bank declared bankruptcy. On March 19, UBS buys Credit Suisse. The exclusion window ends on March 20, 2023.

[49] See Bauer and Swanson (2023) for more detail on the required assumptions.

Finally, this event-study approach assumes that the QT announcements are a surprise. If an announcement is anticipated, it should already be priced into markets, leading to a downward bias in estimates of the impact of QT. This is a potentially serious issue with our analysis, so Appendix A3 reports a lengthy extension attempting to assess the impact on our main results. To do this, we use several methods to identify which QT events in Appendix A2 were a surprise, an exercise that is not straightforward, and in some cases required substantial judgement. With this important caveat, we identify 12 QT events (out of the 39 in the main sample) that involve a large "surprise" component. Then we repeat our main analysis, but only include the surprise QT events. The results do not indicate a stronger impact of "surprise" QT announcements, on yields or other financial market variables, although the sample of "surprise" events is so small that the results can change meaningfully with modest changes in how the events are classified. Therefore, although our estimates of the impact of QT announcements on yields may be biased downward from the news being expected and already priced in, there is not strong evidence that this meaningfully affects the key results reported below.

3.D. Baseline Results

To begin, we focus on the impact of QT announcements on yields at different maturities—a natural starting point for examining the impact of changes in monetary policy. Table 3.1 reports estimates of equation (3.1) when all QT events are pooled together for the two-day change in bond yields (in percentage points), with all data from Bloomberg. QT announcements correspond to an increase in yields of about 4 bps at the 1- through 30-year horizons, while the very short-term impact on 3-month yields is about zero. This is consistent with QT tightening financial conditions through expectations the private sector will have to absorb more debt securities (a portfolio balancing effect), or because QT is interpreted as signaling a tighter stance of monetary policy via the policy rate. Estimates for the other control variables are as expected. A 1pp surprise increase in the policy interest rate corresponds to a significant increase in yields at the 3-month through 5-year horizons, with the effect peaking for one-year yields and then declining. Positive economic data news is also correlated with a significant increase in yields at all horizons of a year and longer, with larger effects over the medium term (2- and 5-year yields), consistent with the market pricing in a greater and more persistent tightening of the policy rate.

Appendix Table A3.3 reports the corresponding results with individual dummy variables for each of the 39 individual QT events, as in equation (3.2). This table is color coded so that positive estimates of β^n are green and negative estimates are red, with darker shading indicating larger relative values. These estimates suggest substantial heterogeneity in the impact of different QT events on yields. For the full table, 59% of the coefficients are positive (particularly for the UK,

Australia, and Canada).[50] About 41% of the coefficients are negative, however (particularly in the US), indicating that QT announcements can also correspond to lower expected yields and consistent with QT not having meaningful effects. In most cases the estimated effect of QT on yields is small, but in some cases the coefficients are large. For example, Sweden's announcement of the start of QT on 04/28/22 corresponded to an increase in 1-year yields of 42bps. These coefficients capture changes in bond yields on the days of QT events that could occur for any reason, however, so these estimates could simply be capturing other, non-QT related news that occurred simultaneously and for which we do not already control.

Table 3.1
Announcement Effects of QT on Government Bond Yields

Results for All QT Events (**except** ***Wind Downs)***						
	Two-day Change in Government Bond Yields (pp)					
	3 month	**1 year**	**2 year**	**5 year**	**10 year**	**30 year**
QT Dummy	0.005	0.048**	0.037*	0.039*	0.042**	0.040***
	(0.010)	(0.020)	(0.020)	(0.020)	(0.018)	(0.014)
Interest Rate Surprise	0.366***	0.445***	0.315***	0.207**	0.109	0.002
	(0.113)	(0.122)	(0.100)	(0.081)	(0.067)	(0.081)
Economic Data Surprise	0.075	0.492***	0.777***	0.792***	0.603***	0.550***
	(0.068)	(0.059)	(0.072)	(0.076)	(0.074)	(0.089)
Observations	***9,521***	***12,534***	***14,595***	***14,764***	***14,858***	***10,371***
R^2	***0.006***	***0.029***	***0.024***	***0.017***	***0.009***	***0.007***

Notes: Coefficient estimates of equation 3.1. LHS variable for each regression is the change in government bond yields in percentage points (from Bloomberg) for the maturity listed at the top calculated over the two-day window from the closing price the day before the QT event to the closing price the day after the QT event. *Interest Rate Surprise* is the difference between any announced policy interest rate on the QT event date versus the interest rate expected on that policy meeting date according to Bloomberg median market estimates just before the meeting. *Economic Data Surprise* is the change in the Citi Economic Surprise Index over the same two-day window as the change in yields. The QT events are listed in Appendix A2 and marked with * for the base sample; this only includes QT events that are new/additional QT (i.e., not winding down QT), that involve government bonds, and that occur from 2014-2023. The sample excludes periods of heightened market volatility around the start of the pandemic, the LDI crisis in the UK and SVB/Credit Suisse Banking turmoil. All estimates include fixed effects and are estimated with robust, Newey-West standard errors . *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

Did QT news affect financial variables other than yields? To test this, we estimate equations (3.1) and (3.2) for other financial variables: a broad stock market index, a broad corporate bond index, the exchange rate versus the U.S. dollar, the Goldman Sachs Financial Conditions Index (FCI), inflation compensation (measured by inflation swaps/breakevens at the 3- and 5-year horizons) and the "convenience yield" of government bonds, measured by the swap spread between the 10-year interest rate swap and the yield on the 10-year government bond.[51] Table

[50] As discussed in more detail below, QT announcements in the US had more muted effects than in other economies, likely due to the extensive preliminary discussions by the Fed in advance of QT. If we exclude the US, two-thirds of the coefficients of the impact of QT announcements on yields are positive.

[51] All data are from Bloomberg. We use inflation swaps to measure inflation compensation when available, but substitute 5-year inflation breakevens for the Euro area as inflation swaps are not available since August 2022. The convenience yield is discussed in more detail in Section 4.

3.2 shows results when all of the QT events are pooled, and Appendix Table A3.4 shows results with a separate dummy for each QT event. (Color coding in the table is now scaled separately for each column to reflect different variances.) In contrast to the results for yields, QT announcements appear to have no consistently significant impact across this range of financial variables. The signs of the estimated effects, however, are in the expected direction; QT announcements generate a fall in the stock index, corporate bond index, inflation compensation at each horizon, and convenience yield as well as an appreciation of the exchange rate and tightening in financial conditions. These effects are only significant at the 5% level, however, for the corporate bond index and convenience yield (corresponding to the results in Section 4 of this paper). The estimated effects for individual countries continue to be heterogeneous.[52]

Table 3.2
Announcement Effects of QT on Other Financial Indicators

Results for All QT Events (**except** ***Wind Downs)***							
	Stock index	**Corp Bond index**	**ER (US$)**	**FCI index**	**Inflation Compensation 3-year**	**Inflation Compensation 5-year**	**Convenience Yield**
QT Dummy	-0.001	-0.002**	-0.003	0.023	-0.012	-0.003	-0.020***
	(0.002)	(0.001)	(0.002)	(0.021)	(0.017)	(0.013)	(0.007)
Interest Rate Surprise	-0.027***	-0.006*	0.020**	0.444***	-0.109**	-0.034	-0.006
	(0.008)	(0.003)	(0.008)	(0.082)	(0.055)	(0.060)	(0.026)
Economic Data Surprise	-0.038***	-0.032***	0.065***	1.076***	0.399***	0.362**	-0.067*
	(0.012)	(0.004)	(0.009)	(0.088)	(0.091)	(0.172)	(0.035)
Observations	***14,265***	***12,201***	***12,860***	***14,964***	***9,694***	***11,513***	***14,553***
R^2	***0.002***	***0.011***	***0.008***	***0.022***	***0.004***	***0.003***	***0.001***

Notes: See notes to Table 3.1 for information on sample and estimation. The Stock and Corporate Bond Indices are broad indices from Bloomberg. The exchange rate (ER) is relative to the US$ (with negative indicating depreciation) and the Financial Conditions Index (FCI) is from Goldman Sachs. Inflation compensation is measured by swaps (or breakevens if not available). The Convenience Yield is measured as the difference between the 10-year swap tenor and 10-year government bond yield. The indices and exchange rate are calculated as percent changes, and the other variables as changes, each over two-days. All data is from Bloomberg except as noted.

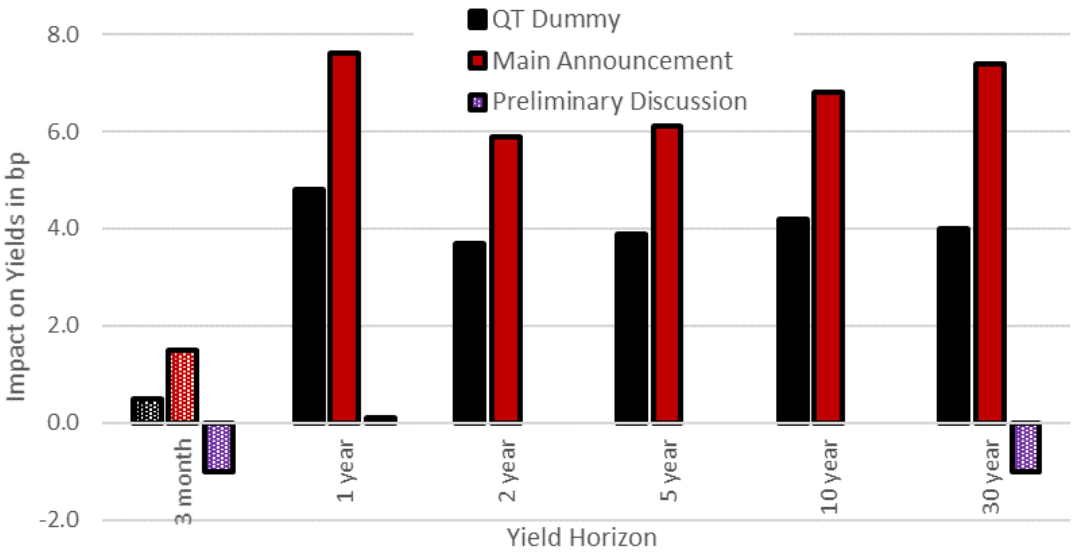
At first glance, this disconnect between the significant impact of QT on yields, but generally insignificant effect on most other financial indicators (except the corporate bond index and convenience yield), is surprising. This is different than during QE—when announcements of central bank asset purchases not only lowered medium- and longer-term yields on government bonds, but also had a portfolio rebalancing effect that impacted the prices of other financial variables (such as boosting equity markets and reducing corporate bond yields, as shown in Selgrad, 2023). This more muted impact of QT on other financial indicators may reflect the smaller impact of QT on yields and risk premia—especially compared to the large movements in yields over 2022 and 2023 from policy interest rates being raised much faster than expected.

[52] For example, in Appendix Table 3.4 the estimated effects on equities are evenly split between positive and negative. Individual QT events are correlated with a fall in the corporate bond index in 69% of the events, appreciation of the U.S. dollar exchange rate in 64% of the events, tightening of financial conditions in 62% of the events, and decrease in the convenience yield in 66% of the events.

Also, even though the estimated effects of QT on a range of financial market variables (other than yields) are usually insignificant, the direction is consistent with a tightening in financial conditions (i.e., a fall in equity markets and appreciation of the exchange rate). Moreover, the estimated effects of QT on the broader financial conditions index—which may better capture the aggregate impact of these multifaceted small effects on a range of variables-- is occasionally significant in the sensitivity tests. These results are all consistent with QT working in the opposite direction as QE, but with much smaller effects.

Could the effects of QT vary based on the type of QT—such as the form of news, transaction, security or country? To assess if different types of QT events have different effects, we estimate equation (3.1) for these different categories of QT, with a subset of the results for yields in Table 3.3 and summarized in Figure 3.1, with another subset of the results for the other financial variables in Table 3.4. All categories are defined in Section 3.A.

Figure 3.1
Impact of QT Announcements on Yields By Type of News



Note: Solid bars indicate estimates are statistically significant (at the 10% level). Bars with white dots indicate coefficients are insignificant. See Tables 3.1 and 3..3 for details and full regression results. .

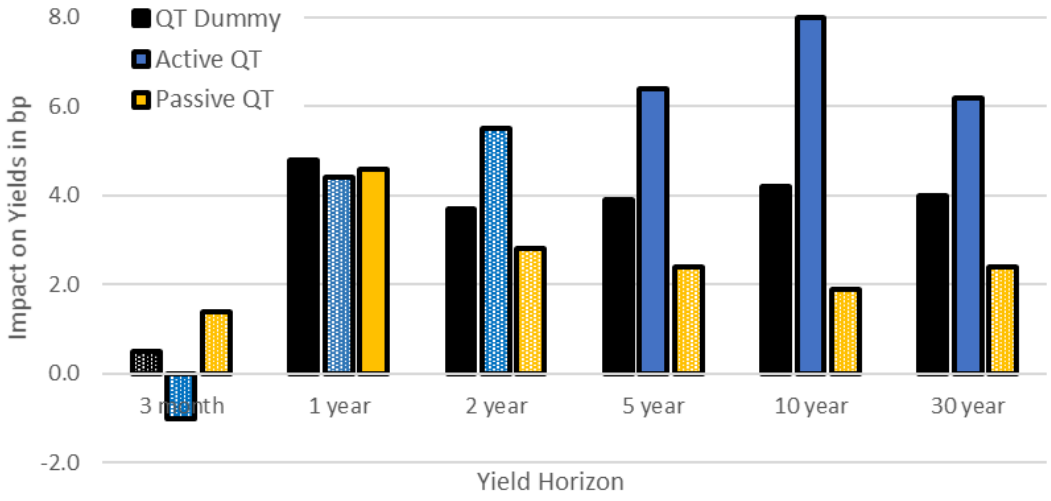
Panel A on each table reports estimates when QT events are classified by the type of news: *Preliminary Discussions*, *Main Announcements*, or *Wind Down* events (which we add to the baseline for this set of results).[53] *Main Announcements, (i.e.,* concrete announcements on how QT will occur) correspond to an increase in yields of about 6-8bps, with the largest effects on 1- and 30-year yields, and somewhat smaller, but fairly steady effects over intermediate horizons. These effects are not only significant, but substantially larger than for the full sample of QT

[53] We do not include the results for *Wind Down* announcements given the limited events in the dataset.

events at most maturities. QT announcements that are the vaguer *Preliminary Discussions*, however, have no significant effects on yields. Each of these types of QT announcements continues to have minimal impact on other financial variables—except for the convenience yield (which falls after all types of announcements) and the corporate bond index (which declines after *Main Announcements*). *Wind Down* announcements are also correlated with a small, positive and significant impact on the stock market (increasing 0.7%) and small effects on inflation compensation at the 5- and 10-year horizons. There are a limited number of *Wind Down* episodes in the sample, however, so this largely reflects the impact of the US 2019 announcement that it would be ending QT sooner than expected.

Panel B of Tables 3.1 and 3.2 show results when the QT announcements are classified by the type of transaction (*Active* vs. *Passive),* with results for yields in Figure 3.2. *Active* QT has a significant positive impact on yields at the 5-year horizon and longer, with the estimated effect larger than for the full sample and just *Main Announcements* at the 5- and 10-year horizons. *Active* QT also has a significant negative impact on the corporate bond index, but no meaningful impact on other financial variables. The announcement of passive QT has a comparable but now significant impact on yields at the 1-year horizon, with much smaller (and insignificant) effects over longer horizons, and has no significant impact on any of the other financial market indicators except the convenience yield. The effects on different segments of the yield curve from different types of QT in Figure 3.2 is noteworthy (and to which we will return below); *Active QT* leads to a steepening of the yield curve and has more impact on corporate bonds, while *Passive QT* generates a modest flattening of the yield curve at the medium and longer end and has more impact on the convenience yield of government bonds.

Figure 3.2
Impact of QT Announcements on Yields By Transaction Type



Note: Solid bars indicate estimates are statistically significant (at the 10% level). See Tables 3.1 and 3.4 for details and full estimation results.

Table 3.3
Announcement Effects of Different Types of QT on Government Bond Yields

	Two-day Change in Yields (pp)					
Panel A: Results by Type of QT News						
	3 month	**1 year**	**2 year**	**5 year**	**10 year**	**30 year**
Main Announcement	0.015	0.076***	0.059**	0.061**	0.068***	0.074***
	(0.013)	(0.028)	(0.028)	(0.028)	(0.026)	(0.018)
Preliminary Discussion	-0.011	0.001	-0.001	0.000	-0.004	-0.010
	(0.013)	(0.018)	(0.025)	(0.024)	(0.018)	(0.012)
Wind Down	-0.006	0.018	0.064	0.032	0.002	-0.014
	(0.007)	(0.027)	(0.055)	(0.051)	(0.034)	(0.021)
Observations	***9,511***	***12,519***	***14,580***	***14,749***	***14,843***	***10,356***
R^2	***0.006***	***0.031***	***0.025***	***0.018***	***0.010***	***0.009***
Panel B: Results by Type of QT Transaction						
	Two-day Change in Yields (pp)					
	3 month	**1 year**	**2 year**	**5 year**	**10 year**	**30 year**
Active QT	-0.011	0.044	0.055	0.064*	0.080***	0.062***
	(0.022)	(0.034)	(0.036)	(0.033)	(0.030)	(0.022)
Passive QT	0.014	0.046**	0.028	0.024	0.019	0.024
	(0.011)	(0.023)	(0.023)	(0.024)	(0.021)	(0.016)
Observations	***9,521***	***12,534***	***14,595***	***14,764***	***14,858***	***10,371***
R^2	***0.006***	***0.029***	***0.024***	***0.017***	***0.010***	***0.008***

Notes: See Table 3.1 for details. All specifications include controls for the *Interest Rate Surprise* and *Economic Data Surprise* variables, as well as country fixed effects. Panel A also includes Wind Down events.

Table 3.4
Announcement Effects of Different Types of QT on Other Financial Indicators

Panel A: Results by Type of QT News							
		Corp Bond			**Inflation Compensation**		**Convenience**
	Stock index	**index**	**ER (US$)**	**FCI index**	**3 year**	**5 year**	**Yield**
Main Announcement	-0.004	-0.004**	-0.003	0.040	-0.028	-0.010	-0.027**
	(0.003)	(0.002)	(0.003)	(0.030)	(0.020)	(0.019)	(0.011)
Preliminary Discussion	0.003	0.000	-0.002	-0.009	0.017	0.010	-0.008**
	(0.003)	(0.001)	(0.003)	(0.022)	(0.026)	(0.016)	(0.003)
Wind Down	0.007***	-0.000	0.004	0.009	0.053***	0.066***	-0.004**
	(0.002)	(0.002)	(0.003)	(0.035)	(0.020)	(0.022)	(0.002)
Observations	***14,250***	***12,186***	***12,850***	***14,949***	***9,684***	***11,498***	***14,538***
R^2	***0.002***	***0.012***	***0.008***	***0.022***	***0.005***	***0.004***	***0.001***
Panel B: Results by Type of QT Transaction							
		Corp Bond			**Inflation Compensation**		**Convenience**
	Stock index	**index**	**ER (US$)**	**FCI index**	**3 year**	**5 year**	**Yield**
Active QT	-0.003	-0.003**	-0.002	0.036	-0.031	-0.022	-0.026
	(0.004)	(0.001)	(0.003)	(0.037)	(0.033)	(0.021)	(0.017)
Passive QT	-0.001	-0.002	-0.002	0.018	0.003	0.008	-0.015**
	(0.003)	(0.002)	(0.003)	(0.024)	(0.018)	(0.016)	(0.007)
Observations	***14,265***	***12,201***	***12,860***	***14,964***	***9,694***	***11,513***	***14,553***
R^2	***0.002***	***0.011***	***0.008***	***0.022***	***0.005***	***0.003***	***0.001***

Notes: See Tables 3.1 and 3.2 for details. All specifications include controls for the *Interest Rate Surprise* and *Economic Data Surprise* variables, as well as country fixed effects. Panel A also includes Wind Down events.

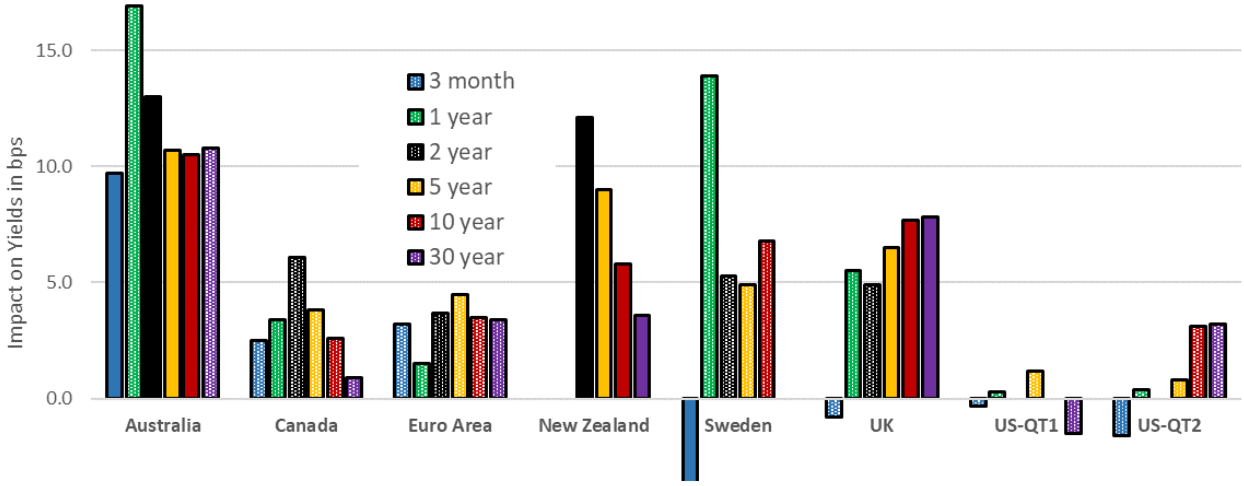
Next, we repeat our estimates of equations 3.1 and 3.2, but now classify QT announcements by the type of security involved (*Government, Corporate, Agency/Mortgage-backed, or State/Municipal/Territory/Local*). The results (not reported) suggest that transactions involving government securities have more consistently significant positive effects on yields than for other types of bonds at horizons of 1-year and longer. This is not surprising as QT in government bonds involve much larger magnitudes. QT involving government bonds also appears to reduce the corporate bond index. The estimated effects of QT announcements for other types of bonds is more mixed, and the small sample sizes suggest any coefficient estimates should be interpreted cautiously (as discussed in Section 3.A).

Finally, we evaluate the impact of QT by economy—calculating both the average impact of individual QT announcements as well as the cumulative effect across all QT announcements to date. To start, we estimate the baseline equation 3.1 with QT announcements categorized by economy, i.e., with *c* for each economy and the US broken into QT1 and QT2.[54] The same caveat about small sample sizes continues to apply—particularly for countries such as New Zealand, Australia and Canada that have limited QT events. With this caution, Figure 3.3 shows the average impact of QT announcements on yields by economy. Several patterns are noteworthy. QT announcements correspond to higher yields at almost all horizons for all economies, ranging from an increase in yields of about 0 to a high of 17bps (for Australia's 1-year yield). QT also corresponds to a fall in the corporate bond index and exchange rate appreciation for most of the sample. Each of these effects is what would be expected from tighter monetary policy. The effects tend to be smaller in the US, however, particularly for pre-pandemic QT, likely reflecting the more gradual and cautious messaging by the Fed (particularly after the Taper Tantrum). As a result, any information on QT in the US was more likely priced in gradually over a longer period of time and harder to capture on specific announcement dates (as highlighted in Waller, 2024).

Next, to calculate the cumulative impact of all QT announcements within each economy, we sum the estimated effects of each individual announcement (from Appendix Table A3.3). These aggregates should be interpreted with caution as they are sums of insignificant coefficients with large error bands for some economies. With this important caveat, Figure 3.4 shows the cumulative effects of all QT announcements for each economy. The largest cumulative effects are in the UK—with the cumulative impact on government bond yields ranging from 44-70bps (across horizons of 1-year and longer). These larger effects for the UK are not surprising as the UK has had the most QT announcements, most of which included news on reducing the balance sheet more aggressively (whether through adding active sales, including corporate, or accelerating the pace of QT). The cumulative impact varies substantially across countries—and even across episodes within the US. For example, in the US, the cumulative impact of QT is close to zero for QT1, but equivalent to about 20bps on 10-year yields during QT2. In the Euro area, the impact of all QT announcements to date corresponds to an increase in government bond yields of about 20bps (for maturities of 2 years and longer).

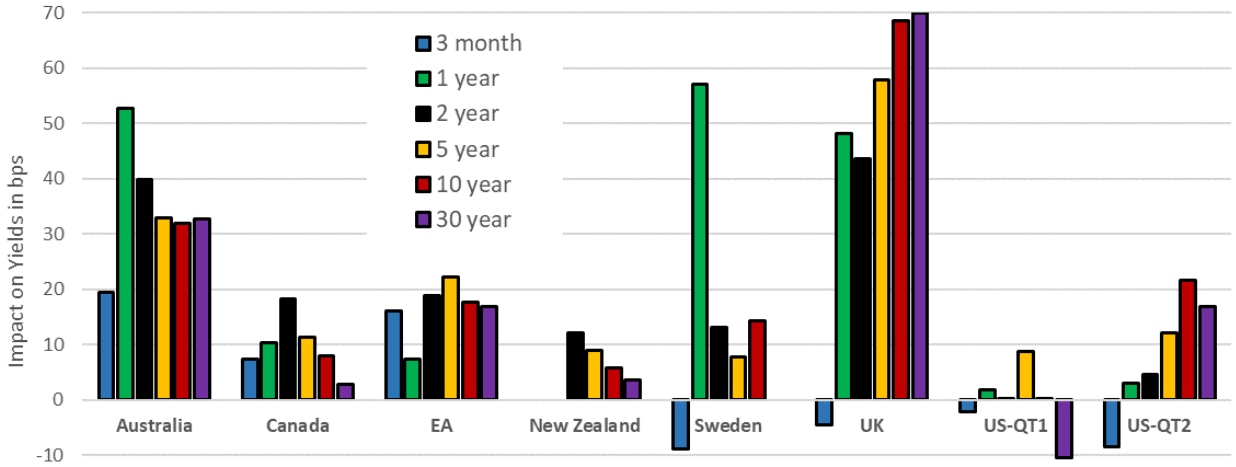
[54] In order to be able to compare the impact of the post-pandemic QT announcements across countries, we only include post-2020 QT announcements, except for the US announcements for QT1 (from 2014-2019) which are broken out separately.

Figure 3.3
Impact of QT Announcements on Government Bond Yields by Country



Notes: Solid bars indicate estimates are statistically significant (at the 10% level). See text accompanying Table 3.1 for definitions and details on estimation.

Figure 3.4
Cumulative Effect of all QT Announcements on Government Bond Yields



Notes: Calculated as the sum of the estimated effects of each individual QT announcement by country, based on estimates in Appendix Table A3.3. These aggregate effects only includes QT events that are new or additional QT (i.e., not *WindDown* events) and only include post-pandemic QT annoucements, except for the US annoucements from 2014-2017, which are included as US-QT-1.

3.E. Channels for QT: Guidance, Duration, and Spillovers

The analysis above generally finds small, positive and significant effects of QT announcements on yields at medium and longer-term horizons, and little consistently significant impact on most other financial market variables. But how does QT affect yields? Does it work through a signaling, portfolio-rebalancing and/or liquidity effect, as found for QE (and discussed in Section 3.A)? If QT works through a signaling effect, is it interpreted as signaling higher policy interest

rates (by strengthening the central bank's commitment to tightening policy) or to lower policy interest rates (as less tightening in the policy rate may be required to achieve price stability)? Does QT have effects outside a country's borders? To shed light on these questions, this section examines if QT works by signaling information on future changes in interest rates and/or through portfolio rebalancing and the term premium. (The next section focuses on liquidity effects.) This section also examines if QT (either for just the Fed or all seven central banks) generates spillovers to other economies. To better capture these effects, we focus on QT events in this section that are *Main Announcements* (as the *Preliminary Discussions* tend to have insignificant effects) and differences between *Active* and *Passive* QT (which affect different segments of the yield curve and may work through different channels).

To begin, we explore whether QT affects yields by providing a signal about the central bank's commitment to future changes in monetary policy. QT could raise expectations for increases in the policy rate in the short term (and possibly in the medium term) if it is seen as strengthening a central bank's commitment to tightening monetary policy and bringing down inflation. Some central bankers have attempted to make this link; for example, in the March 16, 2022 press conference when the Fed gave concrete guidance on plans for balance sheet reduction, Chair Powell stated: "Reducing the size of our balance sheet will also play an important role in firming the stance of monetary policy."[55] On the other hand, QT could also reduce expectations for increases in the policy rate if QT is seen as a substitute for raising the policy rate while tightening monetary policy. This possibility of QT allowing for more gradual, or overall smaller, increases in policy rates is raised in Forbes (2021) and George (2022).[56]

To explore these potential signaling effects of QT, we perform two tests. First, we estimate the correlation between QT announcements and simultaneous changes in expectations for the policy interest rate in 3 or 6 months[57]. The columns on the left in Panels A and B of Table 3.5 report key results. *Main Announcements* and announcements of *Passive* QT correspond to significant increases in expectations for the policy rate in the next 3 and 6 months. This result is consistent with QT announcements providing a signal of a stronger commitment to raising interest rates in the short-term. This result, however, could also be capturing any other messaging or news about faster increases in the policy rate that occurs at the same time as the QT announcements (and which is not otherwise captured in our controls for surprises in the current policy rate or other economic news). This latter explanation could be important for most of our sample; the post-pandemic period when central banks were announcing QT also corresponded to frequent guidance about a more aggressive path of rate hikes in many economies. For example, at the meeting where Chair Powell made his comments about QT playing "an important role in firming the stance of monetary policy", officials also surprised with a hawkish dot plot that guided to a more aggressive tightening path for the fed funds rate.

[55] See the Transcript of Chair Powell's March 16, 2022 press conference here.

[56] For example, George (2022) states: "…more aggressive action on the balance sheet could allow for a shallower path for the policy rate."

[57] We calculate this new control as the change in the 3-month (or 6-month) OIS rate from the day before the QT announcement to the close of the day after the QT announcement, less any change in the announced policy rate that occurs over the same window.

To further explore if QT provided guidance about the future path of monetary policy in addition to any changes in expectations for the short-term policy rate, we repeat the baseline regression in equation 3.1, but add a control for forward guidance as defined above. Each regression continues to control for any surprise in the policy interest rate at the current meeting and other economic data news, but does not capture other guidance released by the central bank at the same time as the QT announcement. Estimates are reported in Panels C and D of Table 3.5.

The results suggest that when investors revise up their expectations for short-term rates (for whatever reason), yields increase significantly at all horizons. (Unreported results also find a tightening in financial conditions and fall in equity and corporate bond indices.) More noteworthy for this exercise, however, are the changes in the estimated coefficients for the QT dummies. QT announcements have a more muted impact on yields when controlling for changes in forward guidance, particularly at shorter horizons, and consistent with some of the effect of QT on short- and medium-term yields working by signaling a higher policy rate in the near term. The effects of QT announcements on longer-term yields are still positive, significant and close to the magnitudes when there is no control for guidance, however, suggesting that some of the effect of QT works through channels other than signals about the short-term path for policy. The effect of *Active* QT on yields also continues to be positive, significant and large, particularly at longer horizons (and roughly the same as estimates with no control for guidance). This suggests that although *Passive* QT may impact yields through signaling a stronger commitment to tighter monetary policy in the short-term, *Active* QT primarily affects yields through other channels, particularly channels that impact longer-term-yields.

Another channel through which QT announcements could affect bond yields—and especially medium- and longer-term yields -- is the portfolio-rebalancing channel. As discussed in Section 3.A, several papers have shown that QE worked at least partly by increasing demand for other duration assets held by the private sector and lowering risk premia. This corresponded to greater effects on longer-term yields, a rise in the prices of duration assets (such as equities and corporate bonds), and a decrease in the term premium.

Our baseline analysis in Section 3.D, however, finds no significant impact of QT announcements on equities, and mixed effects on corporate debt. These results (in the middle of Table 3.5, Panels A and B) continue to provide limited evidence that QT announcements generate meaningful portfolio rebalancing. Only *Active* QT appears to cause a significant shift away from corporate debt, and no form of QT has a significant impact on equity indices. This muted evidence of portfolio rebalancing from QT, particularly in equities, could reflect the much slower pace of QT in 2022-2023 compared to the more aggressive QE programs that generated significant portfolio rebalancing during the pandemic and Global Financial Crisis. The larger effects from QE may also reflect that many of these programs occurred when liquidity was constrained and markets stressed. In contrast, QT announcements generally occurred during periods of abundant liquidity and well functioning markets, as discussed in Section 4, such that changes in central bank securities demand would have less of an impact on other asset prices.

Table 3.5
Channels for QT: Forward Guidance, Portfolio Rebalancing and Duration

Panel A: Main Announcements

	Forward Guidance		Rebalancing		Duration	
	3 month	6 month	Equities	Corporates	Term Premium	10y-2y
QT Dummy	0.023***	0.035**	-0.004	-0.004**	0.011	0.068***
	(0.009)	(0.016)	(0.003)	(0.002)	(0.008)	(0.026)
Observations	***14,947***	***14,943***	***14,251***	***12,191***	***14,853***	***14,844***
R^2	***0.093***	***0.070***	***0.002***	***0.012***	***0.001***	***0.010***

Panel B: Active vs. Passive QT

	Forward Guidance		Rebalancing		Duration	
	3 month	6 month	Equities	Corporates	Term Premium	10y-2y
Passive QT Dummy	0.020***	0.028**	-0.001	-0.002	0.001	0.019
	(0.007)	(0.013)	(0.003)	(0.002)	(0.006)	(0.021)
Active QT Dummy	-0.000	0.000	-0.003	-0.003**	0.014	0.080***
	(0.016)	(0.024)	(0.004)	(0.001)	(0.012)	(0.030)
Observations	***14,961***	***14,957***	***14,265***	***12,201***	***14,867***	***14,858***
R^2	***0.093***	***0.069***	***0.002***	***0.011***	***0.001***	***0.010***

Panel C: Controlling for Forward Guidance at the 3-month Horizon for Policy Rate, Main Announcements Only

	Two-day Change in Yields (pp)				
	1 year	2 year	5 year	10 year	30 year
QT Dummy	0.049*	0.033	0.038	0.049**	0.058***
	(0.027)	(0.027)	(0.027)	(0.025)	(0.018)
Forward Guidance, 3 months	1.042***	1.122***	0.989***	0.792***	0.677***
	(0.056)	(0.054)	(0.054)	(0.051)	(0.057)
Observations	***12,520***	***14,573***	***14,742***	***14,836***	***10,357***
R^2	***0.294***	***0.222***	***0.138***	***0.082***	***0.062***

Panel D: Controlling for Forward Guidance at the 3-month Horizon for Policy Rate, Active vs. Passive QT

	Two-day Change in Yields (pp)				
	1 year	2 year	5 year	10 year	30 year
Passive QT Dummy	0.023	0.007	0.004	0.003	0.012
	(0.022)	(0.023)	(0.023)	(0.021)	(0.016)
Active QT Dummy	0.041	0.055**	0.064**	0.080***	0.063***
	(0.025)	(0.027)	(0.026)	(0.024)	(0.017)
Forward Guidance, 3 months	1.042***	1.125***	0.991***	0.794***	0.678***
	(0.055)	(0.054)	(0.054)	(0.051)	(0.057)
Observations	***12,534***	***14,587***	***14,756***	***14,850***	***10,371***
R^2	***0.293***	***0.222***	***0.138***	***0.082***	***0.062***

Notes: Panels A and C report coefficient estimates of equation 3.1, except only for QT events that are *Main Announcements*. Panels B and D include all events (except *Wind Down*), but categorizes events as *Passive* or *Active* QT. Forward Guidance is defined as the change in the 3-month OIS from the day before the QT announcement to the end of the day after the announcement. Equities and Corporates are the broad equity index and corporate bond index defined in Table 3.2. 10y-2y is the 10-year yield minus the 2-year yield and Term Premium is measured using Cozzi (2023). All specifications continue to include controls for the *Interest Rate Surprise* and *Economic Data Surprise* variables, as well as country fixed effects. Estimates use robust, Newey-West standard errors. See notes to Table 3.1 for additional information on definitions, sample, and estimation. *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

Even if QT does not generate meaningful or measurable portfolio rebalancing, however, it could still affect the pricing of duration and/or term premium. To test this, the right side of Table 3.5 (Panels A and B) tests for an impact of QT announcements on the spread between the 10-year and 2-year bond yield and a measure of the term premium (used by Deutsche Bank[58]). QT announcements, particularly those for *Active* QT, are correlated with a significant steepening of the yield curve (as measured by the 10y-2y spread) and an increase in the term premium (albeit this is usually insignificant). In contrast, passive QT is usually not significantly correlated with either measure. This is consistent with the results in Figure 3.2 (and Table 3.3) which suggest *Active* QT corresponds to a larger increase in yields at longer durations and a steepening of the yield curve, while passive QT tends to be correlated with larger increases in yields at the shorter end of the curve (and a flattening of this part of the curve).

As a final exploration of the channels by which QT works, we also test if QT announcements by the Fed, or other central banks, generate spillovers to the other economies in our sample. To test this, we add a dummy variable to equation 3.1 that is equal to one if QT is announced by the Fed, or any central bank (including the Fed) in our baseline sample.[59] We also control for any interest rate surprise in the US and/or other economies at the same time. Table 3.6 shows that the direct effects of QT announcements are basically identical to our baseline.

More noteworthy are the estimates of the spillover effects of QT. There are modest spillovers of new or additional QT in the US on government bond yields at the 2- to 10-year horizons, as well as on corporate bond indices and broader financial conditions. Moreover, the US announcement in March 2019 that it would wind down QT earlier than expected is correlated with a significant decline in yields at all horizons greater than 3-months. This announcement, however, occurred at the same time that the Fed released a new dot plot that revised down the path for the policy interest rate, so it is impossible to identify how much of the effect on yields was directly from QT, or from the guidance in the dot plot, or an interaction through which QT reinforced the signal from changes in the dot plot. Moreover, there is only one *Wind Down* episode, so it is impossible to say anything concretely about the significance of these estimates.

Shifting to panel B, QT announcements in the full sample have spillover effects on other economies that are small and significant at the 10% level for yields at several maturities. More specifically, QT announcements tend to increase 1-year and 10-year yields by about 6-8bps in the economy announcing the QT, and simultaneously increase yields in other economies by 1-2bps (at the same horizons). QT announcements appear to have larger spillover effects in other economies through a general tightening of financial conditions (as found for US QT) as well as a decline in equity and corporate bond indices. These results could reflect a direct effect of higher yields in the economy announcing QT, but could also reflect a different type of signaling effect—that QT news in one country is interpreted as increasing the likelihood of QT in others.

[58] The term premium is proxied by the 10y-5y adjusted for the beta to the 2yr yield. This is highly correlated (>90%) with standard calculations of the term premium for the US. For details on the calculation, see Yared (2020) and Cozzi (2023).

[59] This dummy variable is set to zero for the central bank announcing QT, as we continue to measure the direct effect of the QT announcement on the economy making the announcement.

Table 3.6
Spillovers from QT

Panel A: Spillovers from QT in the US (Main Announcements, with Wind Down)

	Two-day Change in Yields (pp)						Stock	Corp	
	3 month	1 year	2 year	5 year	10 year	30 year	index	Bond	FCI index
QT Dummy (own country)	0.015	0.076***	0.059**	0.061**	0.068***	0.074***	-0.004	-0.004**	0.040
	(0.013)	(0.028)	(0.028)	(0.028)	(0.026)	(0.018)	(0.003)	(0.002)	(0.030)
US QT Spillover	0.003	0.014	0.029***	0.034***	0.034***	0.018	0.002	-0.002***	0.030***
	(0.005)	(0.013)	(0.011)	(0.009)	(0.010)	(0.012)	(0.003)	(0.001)	(0.011)
US WindDown Spillover	-0.009	-0.032***	-0.037***	-0.056***	-0.068***	-0.068***	-0.003	0.003**	-0.048
	(0.011)	(0.009)	(0.008)	(0.011)	(0.012)	(0.020)	(0.002)	(0.001)	(0.038)
Observations	***9,509***	***12,520***	***14,581***	***14,750***	***14,844***	***10,357***	***14,251***	***12,191***	***14,950***
R^2	***0.006***	***0.031***	***0.025***	***0.019***	***0.011***	***0.010***	***0.003***	***0.013***	***0.024***

Panel B: Spillovers from QT in All Economies (Main Announcements, no Wind Down)

	Two-day Change in Yields (pp)						Stock	Corp	
	3 month	1 year	2 year	5 year	10 year	30 year	index	Bond	FCI index
QT Dummy (own country)	0.014	0.076***	0.058**	0.061**	0.068***	0.075***	-0.004	-0.004**	0.040
	(0.013)	(0.028)	(0.028)	(0.028)	(0.026)	(0.018)	(0.003)	(0.002)	(0.030)
QT Spillover	0.008*	0.012*	0.009	0.010	0.015*	0.015*	-0.004***	-0.001**	0.021**
	(0.005)	(0.007)	(0.010)	(0.010)	(0.009)	(0.009)	(0.001)	(0.000)	(0.008)
Observations	***9,509***	***12,520***	***14,581***	***14,750***	***14,844***	***10,357***	***14,251***	***12,191***	***14,950***
R^2	***0.007***	***0.032***	***0.025***	***0.018***	***0.011***	***0.009***	***0.003***	***0.013***	***0.023***

Notes: Panel A repeats the baseline analysis from equation 3.1, but adds a dummy variable to control for any spillovers from US QT (measured using US *Main Announcements)* and for the US QT *Wind Down* in March 2019. We also control for any surprises in US interest rates. Panel B controls for spillovers from QT or interest rate surprises in other economies (not just the US) and does not include *Wind Down* events. All regressions also include the controls for own-country *Interest Rate Surprises* and other *Economic Data Surprises, as well as* country fixed effects. See notes to Tables 3.1 and 3.2 for further details. All estimates are robust, Newey-West standard errors. *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

3.F. Summary

To summarize, this series of tests suggests that QT announcements correspond to a small and significant increase in bond yields of about 4-8 bps at horizons of 1- to 30-years. The estimated effects vary meaningfully across economies, ranging from no impact to increasing bond yields by up to 17bps (for Australia) after individual QT announcements, and by up to 69 bps (for the UK) when the individual announcement effects are aggregated by economy since 2021. Also, the effects of QT announcements on yields are larger for *Main Announcements* (which involve concrete information about the start or details of a QT program), for *Active* QT (as compared to *Passive* QT), and for government bonds. QT announcements have less consistently significant effects on a range of other financial market variables—including equity markets, the exchange rate, a financial conditions index, and inflation compensation measures—although QT often corresponds to a fall in corporate bond indices and decline in the convenience yield. There are not enough observations to assess the impact of *Wind Down* announcements, although the US announcement in March 2019 that it would end QT earlier than expected corresponded to a fall in yields at most horizons and adjustments in a range of other financial measures.

The results also provide some evidence for the channels by which QT announcements generate small effects on yields, even when expected by at least some market participants. Some of the impact, especially for *Passive* QT, corresponded to changes in expectations about the short-term path of the policy interest rate and a flattening of the yield curve; QT announcements may provide a signal of central bank commitment to tightening monetary policy in the near term, and thereby correspond to investors revising up their expectations for the policy rate over the next 3- and 6-months (even after controlling for any surprises in the policy interest rate or other economic news on the same date as the QT announcement). This relationship, however, may also reflect forward guidance that occurs at the same time as the QT announcement and is not controlled for in our analysis, including the shift to more assertive language about central banks' commitment to tightening policy and achieving price stability. QT, and particularly *Active* QT, also appears to work through increasing duration risk and steepening the yield curve, although it does not correspond to a measurable portfolio rebalancing effect for equities (as found for QE). QT announcements can also have very small effects on other countries.

It is difficult to compare the magnitude of these effects of QT to those for QE (with the sign reversed). Estimates of the impact of QE vary substantially based on the timing, financial environment, and characteristics of the program, just as our estimates of the impact of QT vary substantially by economy (Figures 3.3 and 3.4) and characteristics of the announcement and program. Critically important, since most QE programs are announced during periods of market stress, they are likely to have much larger effects through the liquidity channel than they would if announced during the more tranquil periods when QT is adopted (Logan, 2024b; Waller, 2024). Also, QE programs announced before 2020 (which constitute the bulk of empirical analysis to date) were usually announced for a fixed quantity, while QT announcements have not generally specified a target for the aggregate reduction in asset holdings (or end date).

With these caveats, Table 3.7 provides several very rough comparisons of the impact of QE and QT announcements, focusing on estimates from event studies and the impact on 10-year government bond yields. Borio and Zabai (2016) surveys evidence from a large set of papers covering different economies and QE episodes, and reports effects ranging from -16 to –107bps. The majority of these episodes, however, are from the periods of heightened market stress during the Global Financial Crisis or subsequent Euro crisis. To assess how these estimates could change as market conditions stabilize, the middle section of the table reports estimates of the impact of different US QE programs: QE1 was a period of extreme market stress, while QE2 and especially QE3 occurred during more normal conditions. As expected, the estimated impact of QE declines meaningfully as market conditions stabilize. For comparison, the bottom of this section reports the comparable estimates from this paper (of the cumulative effects of all QT announcements) during QT1 and QT2 in the US. The estimated effects of QT are still meaningfully lower than for QE when focusing on the 2-day estimates, although the estimated impact of QT2 is in the range of the estimates of QE3 when there was minimal market stress.

Table 3.7
Estimated Effects of QE and QT on 10-year Government Bond Yields

Country	Program	Study	Change in 10-year yield (in bps)	
Survey of empirical studies of QE, pre-pandemic, multiple countries and QE episodes (cumulative effects)				
Multiple	Multiple	Borio and Zabai (2016)	-16 to -107	
US QE programs under different market environments (cumulative effects)			**1-day**	**2-day**
US	QE1	Bauer and Neely (2014)	-123	
	High stress	Gagnon, Raskin, Remache, and Sack (2011)	-91	-105
		Krishnamurthy and Vissing-Jorgensen (2011)		-107
		Yellen (2011)	-91	
US	QE2	Bauer and Neely (2014)	-23	
	Modest stress	Ehlers (2012)	-14	-40
		Krishnamurthy and Vissing-Jorgensen (2011)		-30
		Krishnamurthy and Vissing-Jorgensen (2013)	-18	
		Yellen (2011)	-15	
US	QE3	Bauer and Neely (2014)	-14	
	Minimal stress	Krishnamurthy and Vissing-Jorgensen (2013)	-3	
US	QT1	DF&L (2024)		+0.1
	QT2	DF&L (2024)		+21
QE programs during periods of low market stress				
Sweden	QE 2015	DF&L (2024), individual QE announcements		-7
UK	QE 2016	DF&L (2024), individual QE announcement		-13
Sweden		De Rezende (2016), cumulative effects	-39	
Sweden	QE 2015	DF&L (2024), cumulative effects		-39
Results from this paper; Du, Forbes and Luzzetti (2024)				
Mutiple	QT	Cross-country results, individual QT announcements		+4 to +8
Mutiple	QT	Individual country results, individual QT announcements		0 to +17
Mutiple	QT	Individual country results, cumulative effects		0 to +69
Mutiple	QT	Average of individual country results, cumulative effects		+21

Notes: DF&L (2024) is Du, Forbes and Luzzetti (2024), either as reported in Section 3 or estimated for Sweden in 2015 and the UK in 2016 using the baseline specification in equation 3.1. Cumulative effects are summed across all announcements relevant for the given country and QE/QT episode.

The third section of the table then shifts to outside the US and compares the estimated effects of two additional QE episodes that occurred under relatively stable market conditions: Sweden in February 2015 and the UK in August 2016. In each of these cases, QE was adopted in order to provide stimulus and boost inflation to the target (and in Sweden's case, to also moderate the expected appreciation of the krona). Most important for this comparison, QE was not adopted to provide extra liquidity or address issues around market functioning.[60] In Sweden, De Rezende

[60] For example, De Rezende (2016) states: "One important aspect of the Swedish program is that it was not aimed at providing extra liquidity to restore the functioning of markets." In the UK, the 2016 QE was announced several weeks after the Brexit vote in response to concerns economic growth would slow sharply and with limited ability to provide stimulus by lowering the policy rate due to constraints with the lower bound. The brief period of market volatility around the Brexit vote had already ended.

(2016) documents six announcement dates from February 12, 2015 through October 28, 2015, and in the UK there was only one announcement date of additional QE (on August 4, 2016). De Rezende (2016) estimates that the aggregate impact of the Swedish QE announcements was to lower 10-year bond yields by 39bps (based on one-day windows). To better compare these results to those in this paper, we use this paper's methodology to estimate the impact of the Swedish and UK QE announcements. These individual QE announcements correspond to a decline in 10-year government bond yields of 6.5bps in Sweden and 13.2bps in the UK, such that the aggregate effects across all announcements are to decrease 10-year government bond yields by 39bps in Sweden (identical to the De Rezende, 2016 estimates) and 13bps in the UK.[61]

The bottom section of the table summarizes the comparable estimates from throughout this section—including the effects of single QT announcements from the panel or from individual economies, as well as the cumulated effects of all QT announcements within each economy (individually or averaged across the sample)—which are most comparable to the estimates at the top of the table and from the individual US QE programs. The estimated effects of QT announcements are meaningfully lower than those of QE announcements in general, but comparable to those of QE during non-stressed periods. More specifically, and focusing on the effects over two-day windows (which tend to be larger), the non-stress QE announcements in Sweden and the UK correspond to declines in 10-year government bond yields of 7-13 basis points—above the average effect of QT announcements in the panel but within the top of the range for individual country announcements (with signs reversed). Turning to the cumulative effects for economies with multiple events, QT increased bond yields by 21bps on average, which is roughly half the comparable effects of US QE2 or the Swedish QE, but potentially in-line with the cumulative effects of QE3 (for which there are not comparable estimates over 2-day windows).

All in all, these results are consistent with QT working in the opposite direction of QE, but with meaningfully smaller effects than QE when <u>not</u> controlling for the broader financial environment during which these programs are launched. Any comparison of the effects of these programs under the same financial conditions is challenging given their different goals and structures (and the limited use of QE during non-stress periods and of QT during stressed periods). Nonetheless, the very rough comparisons of QE and QT during more stable financial conditions continues to suggest that QT works in the opposite direction of QE and with smaller effects, but the magnitudes are more comparable (and much closer for certain countries and specific QE/QT episodes).

[61] We repeat the baseline estimates from equation 3.1, except instead of including a dummy variable for QT, include dummy variables for these QE announcements (and exclude all QT announcement dates from the sample). These two QE episodes correspond to a fall in bond yields from 4 –15bps for maturities from 1- to 30-years.

4. Implementation Effects of QT

This section explores the implementation effects of QT. We divide our analysis into three parts. First, we build on the approach in the previous section on the effects of QT announcements to examine the effects of QT implementation on the pricing dynamics of government bonds. Second, we study the cumulative effects of implementing QT, so far, on the liquidity balances of the banking system and overnight funding spreads. Finally, we discuss the effects of QT implementation on the "convenience yield" and liquidity of government bonds.

4.A. Effects on Government Bond Pricing

During the process of QT, central banks reduce their holdings of government bonds. Did the implementation of QT (as compared to announcements of QT, as analyzed in the last section) affect the pricing of government securities and the functioning of government bond markets? The overall tightening of the monetary policy stance (whether from QT, or other changes in guidance or the policy rate that often occur around the same time) increases government bond yields, and thus it is empirically challenging to distinguish the effects of QT implementation from the overall change in monetary policy. Focusing on changes that occur on the specific dates on which QT is implemented, however, can help identify the effects—as the asset sales or roll-off that occur as part of QT often do not occur on the same date as announcements related to monetary policy meetings. In this subsection, we use these narrow implementation dates to examine the effects of QT on government bond yields in two ways. First, we compare the one-day change in government bond yields on QT implementation dates (either passive or active) versus on non-QT dates. Second, for countries conducting active QT, we compare the changes in the yields on government bonds sold by central banks (referred to as the QT securities) versus the ones not sold by central banks. Under either empirical specification, we do not find significant pricing effects associated with QT implementation.[62] We report the details of these analyses in Appendix A4.

The lack of significant differences in the yield dynamics between QT dates and non-QT dates, and between QT securities and non-QT securities, suggests that the implementation of QT has not caused obvious distortions in the pricing of government bond securities, in line with the central banks' intentions.[63] These results are not entirely surprising for several reasons. First, passive QT simply lets the bonds in central banks' portfolios mature without transferring ownership, so does not directly affect secondary market bond pricing. In addition, the passive QT dates are known ex-ante as the maturity profile of central bank holdings is public information, so there is no news when the securities expire. Second, central banks have specifically crafted active QT plans to reduce the price impact in the secondary market. For

[62] We report results based on one-day changes in yields for QT implementation effects instead of the two-day changes previously used in the announcement effect section, because we expect the pricing effects, if there are any, to be most pronounced on the implementation dates. Sensitivity tests using two-day changes to test for the effects of QT implementation on government bond pricing also find no significant impact.

[63] Ramsden (2023) finds similar results for the U.K. gilt market.

example, the BoE adopted a "demand-led" approach, under which the BoE has discretion in accepting bids from market participants and is sensitive to the demand appetite for individual securities (Alexander et al., 2023). The RBNZ sells the bonds back to the New Zealand Treasury (the New Zealand Debt Management) rather than back to the market to avoid direct secondary market pricing effects (RNBZ, 2022). The Riksbank sells bonds during recurring auctions and reserves the rights to reject bids if the price deviates significantly from the market price (Riksbank, 2023). Third, debt management offices are aware of the schedule for active and passive QT well in advance, and can adjust the timing and structure of debt issuance to avoid dislocations. Finally, the expected impact of QT on yields may have already been priced in when QT plans were announced (see Section3*).*

These results, however, are subject to one important caveat. This analysis has, so far, focused on the one-day change in government bond yields on implementation dates. While these effects appear to be minimal, QT could have cumulative stock effects on government bond yields that are not captured using this methodology. Therefore, we next study the stock effects of QT on the liquidity and functioning of money markets and government bond markets more broadly.

4.B. Effects on Bank Liquidity and Overnight Funding Spreads

This section shows that the process of QT generally reduces the amount of liquidity balances in the banking system. In turn, as the level of bank liquidity balances decline, the demand for liquidity puts upward pressure on overnight rates.

Of the central banks in our sample, the Fed, BoE and ECB launched QE and switched their monetary policy implementation frameworks from corridor to floor systems following the 2008-09 global financial crisis. The BoC, RBA and RBNZ, by contrast, launched QE following the 2020 Covid pandemic and moved to an effective floor system at that time.[64] Under a floor system, central banks would like to ensure that the supply of reserves is ample so that the banking sector is satiated with excess liquidity (see Logan, 2023 and Schnabel, 2023). However, there is significant uncertainty regarding the level at which liquidity transitions from being ample to scarce (i.e., the "lowest comfortable level of reserves"). The US experience with QT from 2017-2019 (referred to as QT1 below) offers a valuable lesson. At the end of QT1, the level of aggregate reserve balances reached $1.4 trillion in September 2019, an extremely high level, seemingly, compared to the $10 billion reserve balance prior to the 2008-09 global financial crisis. U.S. money markets experienced major stress on September 16-17, however, in response to cash demand shocks; the U.S. repo rate reached over 10 percent and the federal funds rate printed above the upper end of the target range. In response, the Fed re-launched their repo facility to primary dealers and began to purchase Treasury bills to ensure that ample reserves were restored in the banking system.

[64] The only exception to the floor system post-pandemic in our sample is the Riksbank, which has maintained a corridor system by running weekly market operations to manage liquidity in the banking system. Riksbank certificates are issued to absorb excess liquidity in the banking system as a result of pandemic asset purchases.

The demand for reserves under the new post-GFC regulatory environment and the importance of reserves for payments and money market liquidity have been actively studied recently. Several main themes have emerged from academic and policy discussions. First, post-crisis financial liquidity regulations have significantly increased the demand for reserves, so the "kink" in the reserve demand curve between the flat portion and the upward sloping portion is much further out. Second, reserves play a pivotal role in facilitating intraday payments and money market intermediation (Correa, Du and Liao, 2020; Duffie, Copeland and Yang, 2021). No other safe asset, such as Treasury securities, repo or foreign exchange swap lending, are perfect substitutes for holding reserves. Finally, the relationship between the aggregate level of reserves and changes in the overnight rate offers some clues into whether the total reserve supply is abundant (Afonso et al., 2023; Lopez-Salido and Vissing-Jorgenson, 2023). More specifically, when reserves become scarce, overnight funding rates tend to be more sensitive to changes in reserve balances.

Figure 4.1
Reduction in Central Bank Total Assets, Securities Holdings and Bank Liquidity During QT

Notes: The reductions in total assets and total securities holdings are calculated from the corresponding items in central bank balance sheets. The reductions in bank liquidity balance are derived from different liability items for different countries as follows, ECB: liability to euro-area credit institutions related to monetary policy operations; BOE: reserve balance; Fed: reserve balance; RBA: exchange settlement balance; BOC: Canadian dollar deposits of members of Payments Canada; RNBZ: deposits; and Riksbank: the sum of the liability to Swedish credit institutions related to monetary policy operation denominated in Swedish kroner and Riksbank certificates. The sample period is between the start of the QT in each country and December 2023.

Figure 4.1 shows the cumulative reductions in the total assets, securities holdings and bank liquidity balances (reserves, deposits or settlement balances) as a percentage of GDP for the central banks in our sample since the start of QT until December 2023 (or until the end of QT in the case of U.S. QT1). In 7 of the 8 QT episodes so far, the reduction in the securities holdings of the central bank (the orange bar) translates into a similar reduction in the total assets of the

central bank (the red bar). The single exception is New Zealand, where the decline in QT securities holdings was largely offset by an increase in other asset items, including an increase in foreign currency securities and repo lending by the RBNZ.

Furthermore, the reduction in central bank securities holdings and total assets have largely translated into a similar reduction in the liquidity balances of the banking system (blue bar). In other words, QT generally reduces bank liquidity balances. A notable exception is QT2 in the US (i.e., the post-pandemic QT in the US). Between the start of QT2 in June 2022 and December 2023, Fed total assets and securities holdings both declined by 7% of GDP, while total reserve balances only declined by 0.7%. The decline in the other non-reserve liability items at the Fed accounted for most of the balance sheet run-off. In particular, the ON RRP, where nonbanks park cash at the Fed, declined by 4.5% of GDP (green bar).

Figure 4.2 shows the evolution of the level of overnight funding spreads over these QT windows. In all countries with a floor system, average overnight funding spreads were negative three months prior to the start of QT. That is, overnight money market rates were lower than the deposit rate paid to banks by the central bank.[65] A negative overnight funding spread over the reserve remuneration rate generally reflects the fact that some nonbanks with excess liquidity do not have access to the central bank deposit facility, and therefore are willing to lend to banks at lower rates than what the banks receive from the central bank.

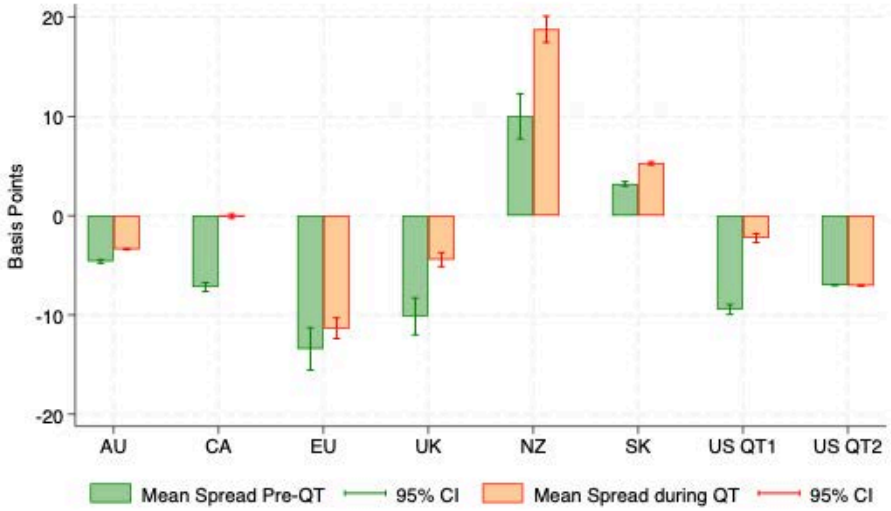
Since each QT episode began, overnight spreads increased 4.2 basis points from -4.7 basis point to -0.5 basis point, on average, across all the episodes in our sample. Given the average standard deviation of the overnight fund spread within a country is only 1.6 basis points and the level of the overnight spread is small, a 4.2 basis point increase in the average spread is notable. The overnight funding spread increased in each individual QT episode (so far) with a single exception, QT2 in the US. The spread between the federal funds rate and the interest on reserves (the FF-IOR spread) in the U.S. has been little changed since the start of QT2. Nonetheless, the spread between the Secured Overnight Financing Rate (SOFR) and the IOR in the US has moved up over the last few months in 2023, and on average has risen 1 basis point over the entire duration of QT2 so far. Meanwhile, the spread of the 75th percentile of the repo rates used in the SOFR calculation over the IOR has moved up 4 basis points on average.

The limited change in overnight funding spreads in the US to date is consistent with the fact that banks' reserves have not declined much during U.S. QT2, and non-reserve liabilities (ON RRP by nonbanks, in particular) kept pace with the decline in Fed assets. As of January 2024, the ON RRP facility currently has a balance of $680 billion, significantly lower than the $2.2 trillion

[65] In New Zealand, the overnight money market benchmark published by the RBNZ captures interbank trading. Since the RBNZ switched to the floor system and remunerated all settlement balances at the Official Cash Rate (OCR) in 2020, banks have little incentives to lend at a rate below the OCR, resulting in very low levels of trading in the overnight interbank market. Out of the 249 trading days in New Zealand in 2023, the RBNZ only published the overnight interbank cash rate index for 52 days. Therefore, we choose not to use the overnight interbank cash rate, but instead use the highly liquid one-month bank-bill rate as the short-term funding rate for New Zealand. Due to the difference in tenors, the one-month bank-bill rate is higher than the overnight OCR.

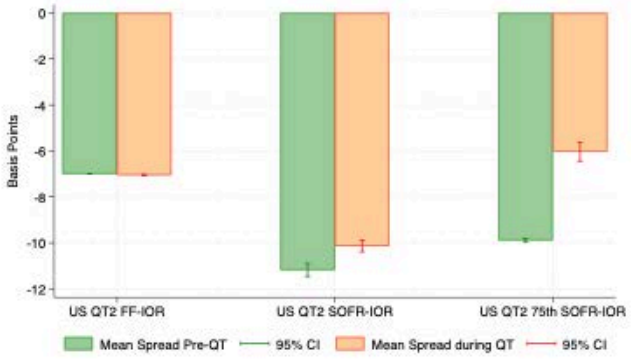
balance in June 2022 at the start of QT2. As the balance in the ON RRP facility declines further, upward pressure in overnight money market rates will likely become more notable (Logan, 2024a). The U.S. QT2 experience so far provides a clear contrast to the QT1 experience. Throughout QT1, the ON RRP balance was close to zero, and QT1 directly translated into a large reduction in reserve balances. The FF-IOR spread turned from negative to positive during U.S. QT1, on average moving up by 7 basis points.

Figure 4.2.
Panel A. Average Short-Term Funding Spreads Before and During QT Across Countries



Notes: This figure plots average short-term funding spreads before and during QT. The green bar denotes the average spread over 30 days prior to the start of QT. The orange bar denotes the average funding spread between the start of QT and December 2023 (or until September 2019 for US QT1). The 95 percent confidence intervals for the means are shown in the figure. The following funding spreads are used: Australia: Overnight cash rate - Cash rate target; Canada, CORRA - Policy rate; Euro area, ESTR - Deposit rate; New Zealand, 1M bank bill - Official Cash Rate; Sweden, T/N STIBOR - Deposit rate; UK, RONIA - Bank rate; US, Federal funds – IOR.

Panel B. Average Overnight Funding Spreads Before and During U.S. QT2



Notes: This figure plots average short-term funding spreads before and during U.S. QT2. The green bar denotes the average spread over 30 days prior to the start of QT. The orange bar denotes the average funding spread between the start of QT and December 2023 (or until September 2019 for US QT1). The 95 percent confidence intervals for the means are shown in the figure. Three types of funding spreads are shown: federal funds over the IOR; SOFR over IOR; and the 75th percentile of the repo rate in the SOFR calculation over the IOR.

This negative relationship between the level of reserves and overnight interbank rates is confirmed in 6 out of the 7 countries in our sample during the post-pandemic QT. Table 4.1 shows monthly regression results of overnight funding spreads on the reserve-to-GDP ratio (upper panel) and on the share of reserves as a fraction of total assets of banks domiciled in the respective economy (lower panel). The pooled panel results suggest that a 1 percent reduction in the reserves-to-GDP ratio increases the overnight funding spread by 0.9 basis points, and a 1 percent reduction in the reserves-to-bank-assets ratio increases the overnight funding spread by 2 basis points.

Table 4.1
Regression of Overnight Funding Spreads
on the Reserve-to-GDP Ratio and the Reserve-to-Bank Assets Ratio

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	AU	CA	EA	NZ	SK	UK	US	Panel
Reserves Over GDP	-0.19**	-0.52***	-0.40	0.08	-6.36***	-0.60**	-0.75*	-0.92***
	(0.08)	(0.12)	(0.25)	(0.09)	(0.80)	(0.28)	(0.40)	(0.20)
	AU	CA	EA	NZ	SK	UK	US	Panel
Reserves Over Bank Assets	-0.45**	-1.63***	-1.13*	0.12	-12.98***	-1.96*	-1.04***	-2.09***
	(0.20)	(0.35)	(0.58)	(0.16)	(1.23)	(1.13)	(0.39)	(0.48)

Notes: Columns (1)-(7) report regression results of end-of-month overnight funding spreads on the monthly reserve-to-GDP ratio and the monthly reserve-to-bank-asset ratio, respectively. Column 8 reports the pooled panel results with country fixed effects. The sample period is between January 2015 and December 2023. Newey-West standard errors with 6-month lags are reported in the parentheses, *** p<0.01, ** p<0.05, * p<0.1.

In summary, post-pandemic QT has so far proceeded with no economy in our sample encountering a major central bank liquidity-induced money market stress episode. However, our results are consistent with QT reducing banking sector liquidity and thereby tightening overnight funding conditions. It is impossible to estimate the exact impact of QT though, as other changes in financial conditions since the pandemic (such as increased debt issuance in many economies), could also be contributing to these trends. Nonetheless, we cannot rule out the risk that a continuation of QT programs could generate stress episodes in the future, particularly if central bank balance sheets decline by another $2tn over the next two years (as projected in Section 2 assuming central banks continue shrinking balance sheets according to current program parameters). Fortunately, the liquidity stress episode following U.S. QT1 in September 2019 has offered valuable lessons, and several central banks have introduced standing repo facilities that can act as liquidity backstops that should hopefully reduce the risk of future stress episodes.

4.C. The Convenience Yield and Liquidity of Government Bonds

This subsection explores the impact of QT implementation on the "convenience yield" and liquidity of government bonds.

Swap spread as a Measure of Government Bond Convenience

Existing literature has shown that the convenience yield of safe assets declines in response to the supply of safe assets (Krishnamurthy and Vissing-Jorgensen, 2012). By increasing the supply of the available securities to private market participants, QT can have direct effects on the convenience yield of government bonds. We follow Du, Hébert and Li (2023) and use the swap spread, defined as the spread between the interest rate swap rate and the government bond yield of the same maturity, to measure the convenience yield of government bonds. We find evidence that the swap spread has declined across countries since QT began, indicating a decline in the convenience yield of government bonds. Regression results show consistent evidence that a reduction in central bank holdings of government bonds is a significant driver of the decline in the swap spread.

Appendix Figure A4.1 plots the 10-year swap spread for our sample since 2020. The vertical lines denote the start of post-pandemic QT implementation. The swap spread has generally been trending down since QT began in a majority of the countries. The U.S. has a negative swap spread throughout the period, indicating the 10-year Treasury yield is higher than the interest rate swap rate, and the swap spread has become more negative since QT.[66] Swap spreads in the UK and New Zealand were close to zero at the start of QT and became negative towards the end of 2023. Sweden has the largest decline in the swap spread since QT, by about 70 basis points. In most countries the decline in the swap spread does not directly align with the start of QT, with the former generally lagging the latter, although the two dates coincide closely in Sweden.

Changes in the swap spread could correspond not only to changes in central banks' holdings of government bonds, but also to the outright supply of government bonds. Appendix Figure A4.2 compares the ratio of outstanding government bond securities to GDP for the countries in our sample and suggests the expected positive relationship between swap spreads and government bond supply. The UK and US have the largest government bond markets relative to the size of their economies—at over 80% of GDP—and also have the lowest swap spreads (or the lowest, often negative, government bond convenience yields). Conversely, Sweden has the lowest levels of government debt—only around 20% of GDP—and the highest swap spread (or the highest government bond convenience yield). Although all countries experienced an increase in the government debt-to-GDP ratios during the pandemic, these ratios have leveled off during QT.

[66] A negative swap spread indicates that government bonds are less "convenient" than the interest rate swap. The long-dated U.S. swap spread turned negative after the 08-09 crisis, which was referred to as the "swap spread puzzle". One reason for the negative swap spread post-GFC is that it is more costly for dealer-banks to hold government bonds (which are reported on the balance sheet) than holding the interest rate swaps (which are largely off-balance sheet).

To investigate the relationship between QT and swap spreads, we perform individual country and panel regressions with country fixed effects of the swap spread on the debt-to-GDP ratio and the share of government bonds held by the central bank. Table 4.2 reports results. The convenience yield of government bonds decreases in the supply of the government bonds and increases in the share of government bonds held by the central bank. The panel results suggest that a 10 percent reduction in the share of government bonds held by the central bank reduces the swap spread by 6.4 basis points (holding the supply of the government bonds constant). As of November 2023, the average share of government bonds held by central banks has declined by 8.2 percent in our sample since QT began, so the panel regression results attribute a 5.2 basis point decline in the convenience yield of government bonds to QT. Overall, these results provide evidence that QT has increased the supply of Treasury bonds to the private market and thereby reduced the convenience yield of government bonds.

Table 4.2
Regressions of Monthly Swap Spreads on the Share of Government Bonds Held by Central Banks and the Government Debt-to-GDP Ratio

	(1) AU	(2) CA	(3) EA	(4) NZ	(5) SK	(6) UK	(7) US	(8) Panel
CB Share	1.60***	-0.04	1.00***	-0.48	0.04	1.54**	0.63	0.64***
	(0.21)	(0.32)	(0.16)	(0.51)	(0.32)	(0.73)	(0.71)	(0.11)
Debt/GDP	-3.65***	1.12**	-1.07**	0.48	-3.81**	-0.29	-0.55	-0.43***
	(0.48)	(0.50)	(0.43)	(1.35)	(1.66)	(0.43)	(0.36)	(0.15)
Observations	81	143	100	99	127	121	169	840
R-squared	0.75	0.22	0.67	0.08	0.44	0.27	0.09	0.15

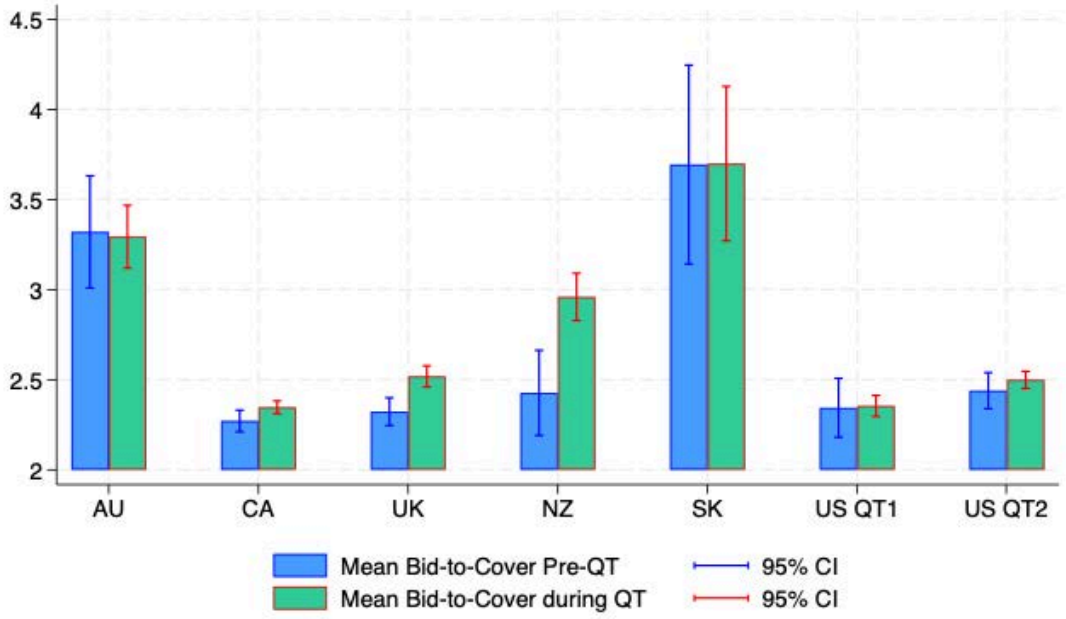
Notes: This table reports monthly regression results of the end-of-month 10-year swap spread on the share of government securities held by central bank and total government securities outstanding over GDP. Columns 1-7 run time series regressions for individual countries. Column 8 runs a panel regression with country fixed effects. The sample period varies across countries depending on data availability and ends in September 2023. Newey-West standard errors with 6-month lags are reported in the parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Government Bond Liquidity

As central banks gradually reduce their holdings of government bonds, one important concern is whether liquidity in the government bond market would deteriorate. Appendix Figure A4.3 plots the Bloomberg government bond liquidity index for the US, UK, Germany, and Canada since 2019. These liquidity indexes are based on the average yield curve fitting error between individual securities and a fitted yield curve. A lower index indicates smaller average yield curve fitting errors, which corresponds to less dispersed government bond prices across securities and better government bond market liquidity. Unsurprisingly, the liquidity index deteriorated in all countries at the peak of the Covid pandemic in March 2020. Over the past two years since the major economies have started QT, however, the liquidity indexes have deteriorated further on net. The average level of yield curve fitting errors in December 2023 is higher than the level in March 2020 in all four countries.

This deterioration in the government bond liquidity index is strongly correlated with elevated interest rate volatility (Duffie et al., 2023), but does not correspond closely to the pace of QT. Appendix Table A4.1 regresses changes in the monthly liquidity index on the change in the interest rate swaption implied volatility and changes in the central bank government securities holdings to GDP. The swaption implied volatility is highly positively correlated with the index; when volatility is high, liquidity is poor. The correlation is particularly strong for the UK, with changes in volatility explaining close to 40% of monthly variations in the liquidity index. In contrast, changes in central bank holdings of government securities are not significantly correlated with monthly changes in the liquidity index.

Figure 4.3.
Summary of Auction Bid-to-Cover Ratio Before and During QT



Notes: This figure plots average bid-to-cover ratios from Treasury auctions. The blue bar denotes the average ratio over 6 months prior to the start of QT. The green bar denotes the average ratio between the start of QT and December 2023 (or until September 2019 for US QT1). We only include auctions for government debt securities over on year. The 95 percent confidence intervals for the means are shown in the figure.

In addition to affecting liquidity conditions in the secondary market, a related concern about the impact of QT is that the absence of central banks at government auctions might affect primary market liquidity. We collect data on the results of past government bond auctions and calculate the average bid-to-cover ratio over time for each of the economies in our sample. Figure 4.3 compares the mean auction bid-to-cover ratio six months prior to the start of QT and during QT. We find that the average bid-to-cover ratio during QT is either little changed or higher relative to the bid-to-cover ratio prior to QT. Therefore, we do not find evidence that QT has weakened demand appetite at government bond auctions.

4.D. Summary

In summary, this section analyzes the effects of implementing QT programs—as compared to announcing them (the focus of the last section). We find no significant pricing effects for government bonds on QT implementation dates—whether the QT occurs through passive run-off or active sales. Over time, the cumulative effect of QT is consistent with: a significant reduction in the liquidity balances of the banking system (with the exception of the post-pandemic QT in the US, so far), a modest rise in overnight funding spreads, and a decline in the convenience yield of government bonds. It is impossible, however, to isolate how much of these changes is directly caused by QT, versus other (potentially related) changes in the economic and financial environment since QT programs began. Finally, we find no evidence that QT has directly worsened the liquidity of government bond markets, nor reduced the demand for government bonds at auctions.

5. The Flow of Funds During QT: Who Steps in as Central Banks Step Back?

This section assesses how QT corresponds to changes in the share of government debt securities held by different types of investors. Our focus is on analyzing which investors increase their holdings as the domestic central bank reduces its holdings. By studying the mechanics of QT through data on the flow of funds, we can gain a deeper understanding of how central bank balance sheet reduction is transmitted to the real economy through asset prices and why its effects may differ across geographies and time periods.

Given the limited historical experience with QT, empirical work on how investors adjust their securities holdings in response to the reduction in central bank balance sheets is also limited. Carpenter, Demiralp, Ihrig and Klee (2013) finds that during QE episodes the Fed purchased securities from a relatively limited subset of investors, most importantly domestic “households”, which include hedge funds. Recent work from the BIS (Eren, Schrimpf and Xia, 2023) estimates investor yield elasticity of demand and links this to the impact of central bank balance sheet adjustments but does not focus on QT episodes. Fang, Hardy and Lewis (2022) finds that the yield sensitivity of demand is highest for nonbank investors in a sample of 95 countries, potentially explaining why these investors absorb a disproportionate share of debt supply as central banks adjust their holdings. Since QT occurs during monetary policy tightening cycles, investor demand for government securities could also be affected by the simultaneous flattening or inversion of the yield curve. For example, Du, Hébert and Li (2023) shows that lower expected excess returns on long-term bonds could dampen demand from real money investors and shift demand to levered funds and primary dealers.

There are also several recent examples of research focusing on the QT experiences in individual economies, cited in the following discussion with the related results. To our knowledge, ours is the first paper to use the recent experience with QT to conduct a cross-country empirical

analysis of the flow of funds for government debt securities. We find evidence of the importance of nonbanks in absorbing the reductions of central banks' government securities holdings, though we also highlight a variety of factors that lead to heterogeneous experiences across economies.

5.A. Data Sources

We leverage two broad data sources. First, we consider cross-country data from the IMF's International Financial Statistics (IFS) database. This contains data on the share of general government gross debt held by various investor types, including domestic and foreign banks, nonbanks, and central banks. These data are available on a quarterly basis from Q1 2004 until Q2 2023 for all countries and on an annual basis for the fourth quarter of each year from as early as 1989 through 2003, though availability varies by country. We then supplement this analysis with country-specific data sources that provide greater granularity about domestic investors.

Our different data sources have advantages and disadvantages. Because the IMF data are more uniform across economies, it allows for a more robust cross-country assessment of the flow of funds in response to QT, including panel regressions. The IMF data also provide a breakdown of foreign holdings between the official and private sectors, a level of detail that is generally not available in country-specific data sources. However, the IMF data are more limited in the breakdown of domestic holdings beyond the bank / nonbank distinction. In particular, the IMF data do not provide details about the domestic nonbank category, a distinction that prior work (and the results below) shows is important. We therefore turn to the country-specific sources for more detailed analysis, especially related to the breakdown of domestic nonbank holdings.

5.B. Main Results

We begin with the IMF's IFS data on general government debt holdings by investor type. Our empirical approach is to consider regressions of the form: change in investor type *j*'s share of securities holdings in country *i* at time *t* on a constant and the change in the domestic central bank's share of securities holdings at time *t*. [67] This baseline regression (Equation 5.1) estimates the average change in investor *j*'s share of securities that corresponds to changes in the central bank's share of securities across all historical periods—including QE, QT and non-QE/QT periods. Importantly, this regression estimates the correlation between the change in the central bank holdings and each investor group's holding of government debt securities and does not identify the causal link between these variables.

$$D\left(Investor\_share_t^{i,j}\right) = \beta_{i,j,0} + \beta_{i,j,1} D\left(CB\_share_t^{i}\right) + \varepsilon_{i,j,t} \qquad (5.1)$$

[67] This specification differs from Carpenter et al. (2013), which uses the nominal securities holdings from the Flow of Funds data in the US and therefore also controls for debt supply by including the change in securities outstanding. Because we consider shares, we drop the securities outstanding variable from the regression. We also estimated regressions including a lagged dependent variable. The results were unchanged.

By construction, any change in the central bank's share has to be completely offset by the other sectors. Therefore, the sum of $\beta_{j,1}$ across all sectors should add up to -1 for each country.

For ease of interpretation, Table 5.1 provides a summary of the regression results, namely the values of $\beta_{i,j,1}$, the coefficient on the change in the central bank's share. The table highlights with asterisks where this coefficient is statistically significant (using robust standard errors) and of the expected negative sign (i.e., the investor buys when the central bank reduces holdings and vice versa). The cells are color coded with more negative values red and positive values green, with the shading determined by the relative values in the table. Results are presented for all economies conducting QT except for the ECB, for which we do not have sufficient data given its later start date.[68] In the last row, results are also shown for a pooled panel regression for each type of investor. For the panel regressions, we weight each economy by relative GDP in USD terms, include country fixed effects, and cluster robust standard errors at the country level. Full regression results are presented in Appendix A5.

Table 5.1
Significance of Change in Central Bank Holdings Across All Time Periods ($\beta_{i,j,1}$)

	Nonbank		Bank		
	Domestic	Foreign	Domestic	Foreign	**Foreign official**
US	-0.96***	-0.15*	0.19	-0.05**	-0.03
UK	-0.72***	-0.09**	-0.08	-0.03***	-0.08**
CA	-0.74***	-0.06***	-0.06	-0.02***	-0.12***
SW	0.10	-0.84***	-0.27	-0.01	0.03
AU	-0.61**	-0.09	-0.22	0.00	-0.08
NZ	-0.20***	-0.33***	-0.32***	-0.05***	-0.09*
Pooled panel	-0.79***	-0.14**	0.03	-0.04**	-0.06**

Note: Table displays the coefficients on the central bank share from equation 5.1 using the IMF's IFS data. Cells are color coded to show relative values with more negative values red and positive values green. Asterisks denote coefficient estimates that are significant at the 1% (***), 5% (**) and 10% (*) levels with the expected sign (i.e., negative).

A few conclusions are evident from this table. First, we find that nonbanks – both foreign and domestic – tend to have the largest adjustments in their portfolios when central banks adjust their holdings. This role for nonbanks is not only statistically significant in almost all countries in our sample, but also large in magnitude. More specifically, the estimates in the pooled regressions indicate that nonbanks offset about 93% of the change in the share of government securities held by the central bank. This is consistent with the empirical analysis detailed previously and our intuition that price-sensitive investors (i.e., nonbanks) are likely to respond most significantly to higher yields driven by changes in the private supply of securities.

[68] More specifically, the ECB started QT in March 2023, and the flow of funds data is only available through 2023Q2.

Second, within nonbanks, domestic nonbanks generally act as a more important offset than foreign nonbanks to changes in central bank securities holdings.[69] In the pooled regressions, of the 93% offset by nonbanks, 79% of the adjustment occurs in domestic nonbanks and 14% in foreign nonbanks. The role of domestic nonbanks is also significant and economically important for most of the countries in the sample.[70]

Finally, there is meaningful heterogeneity across economies—particularly in the role of foreign flows in balancing changes in central bank holdings. For example, changes in foreign official flows are only significant in the UK, NZ, and Canada. Domestic banks are only statistically significant in New Zealand – an economy where each investor type is significant.[71]

The results reported in Table 5.1 estimate how changes in central bank securities holdings correspond to those for other investor groups across a long period of time. But do these relationships differ during QT periods? To assess this question, we also include a dummy variable for QT episodes, which we interact with the change in the domestic central bank's share of securities outstanding. Specifically, we estimate:

$$D\left(Investor\_share_t^{i,j}\right) = \beta_{i,j,0} + \beta_{i,j,1} D\left(CB\_share_t^i\right) + \beta_{i,j,2} D\left(CB\_share_t^i\right) * 1\left(QT_t^i\right) + \varepsilon_{i,j,t} \quad (5.2)$$

In contrast to the results presented in Table 5.1, Table 5.2 finds less evidence of statistically significant changes during QT periods across most economies and investor types.[72] Nonetheless, there are some noteworthy findings. The panel regressions show that domestic nonbanks alter their behavior during QT, becoming more sensitive to changes in central bank security holdings. The weighted average coefficient on the QT dummy interaction term across economies of -0.67 implies that (when combined with the baseline results across all periods) increased demand by domestic nonbanks more than compensated for the reduced shares by central banks. The estimates for the other investor classes are not significant in the pooled regressions, suggesting that, on average, these investors do not change their behavior during QT.

There are some important differences, however, across the individual QT episodes. In the US, there is a meaningful difference in results between QT1 and QT2. During the QT episode from 2017-2019, domestic and foreign banks changed their behaviors in a statistically significant way, absorbing more of the government debt supply than during all periods on average. In contrast, during the post-pandemic QT episode, domestic nonbank investors increased their purchases in a statistically significant way to offset the decline in Treasury securities holdings from the Fed. With QT2 occurring in a significantly compressed timeline relative to QT1, along with a backdrop

[69] This is consistent with the findings for QE in the US from Carpenter et al. (2013) as well as the conclusion from Bank of Canada analysis that nonbanks were likely to increase their shares of government debt holdings during QT in Canada, see Bolduc-Zuluaga, Howell, and Johnson (2022).

[70] The outlier is Sweden, where foreign nonbanks are more important absorbers of government securities, consistent with research showing that foreign investors were more sensitive to Riksbank purchases during QE. See Osterholm (2022).

[71] One reason that all investor types may be significant in New Zealand is that their government debt securities are more evenly held across investor types than other economies.

[72] These results are very preliminary, however, as economies have only been implementing QT for a few quarters in our sample (except for the US which includes the earlier QT episode in 2017-2019).

of aggressive monetary tightening that led to significantly higher yields, it is intuitive that price-sensitive investors, namely domestic nonbanks, played a more significant role in absorbing Treasury securities during the latter episode. We explore the factors behind this importance of the domestic nonbank sector in the US in more detail later in this section.

Table 5.2
Significance of Interaction Term with QT Dummy (i.e., the Additional QT Effect, $\beta_{i,j2}$)

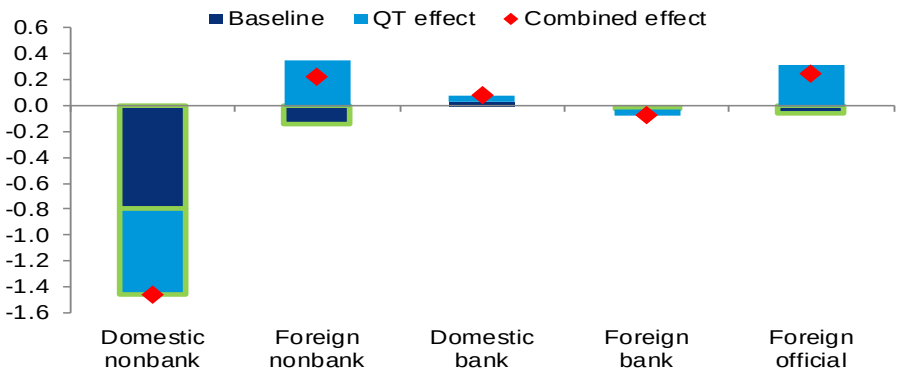
	Nonbank		Bank		
	Domestic	Foreign	Domestic	Foreign	Foreign official
US QT	-0.71	0.36	-0.13	-0.08	0.56
US QT1	0.01	0.53	-1.11**	-0.30***	0.87
US QT2	-1.02**	0.29	0.29	0.01	0.43
UK	-0.06	0.30	0.16	0.03	-0.43*
CA	0.03	0.05	-0.42	0.01	0.32
SW	-2.70***	0.50	1.68	1.47	-0.94
AU	-1.07***	1.30	0.28	-0.09**	-0.42***
NZ	-0.08	-0.52***	0.53	0.01	0.06
Pooled panel	-0.67**	0.35	0.05	-0.04	0.31

Note: Table displays the coefficients on the interaction term between central bank share and QT dummy from equation 5.2 using the IMF's IFS data. Cells are color coded to show relative values with more negative values red and positive values green. Asterisks denote coefficient estimates that are significant at the 1% (***), 5% (**) and 10% (*) levels with the expected sign (i.e., negative).

This more important role for domestic nonbanks in absorbing changes in central bank holdings during QT is also observed in Sweden and Australia, where these investors showed an even greater propensity to substitute for central bank holdings. Also noteworthy is the increased role of foreign official institutions in the UK and Australia, and foreign nonbanks in New Zealand—estimates that are not only statistically significant, but economically meaningful.

Figure 5.1 presents a summary of the results from Tables 5.1 and 5.2. The figure shows the combined response of investor holdings, including both the baseline response over all periods and the additional response during QT episodes, based on the pooled regressions for each of the investor types over our sample period. Coefficient estimates that

Figure 5.1
Response of investor holdings to central bank balance sheet changes from pooled panel regressions



Note: The figure displays the coefficient estimates from the pooled panel regressions in Tables 5.1 and 5.2. The red diamond represents the combined effects during QT periods. Coefficient estimates that are significant at the 5% level or better are shown in bolded green.

are significant at the 5% level or better are bolded in green. This figure punctuates the importance of the domestic nonbank sector in offsetting changes in central bank balance sheets, particularly during QT. In particular, the combined coefficients for the domestic nonbank sector equal -1.46, suggesting that these investors increase their share of government securities holdings nearly 1.5 times the decline in the central bank share on average across economies during QT episodes.

5.C. Results: A Deep Dive into Nonbank Domestic Investors

Given the importance of the domestic nonbank sector in substituting for changes in central bank balance sheets, especially during QT periods, this section leverages the additional granularity of country-specific data sources for a more detailed breakdown of these investors. We focus on the US, UK, Canada and Australia (dropping New Zealand and Sweden due to either data limitations or inconsistencies with the IMF data).[73]

We begin with similar regressions as above and regress the change in the share of each investor type on a constant term and the change in the domestic central bank's share of securities (equation 5.1). We also consider regressions that include the interaction between a QT dummy and changes in the central bank's securities holdings to analyze whether these relationships change during periods of central bank balance sheet reduction (equation 5.2). Due to a lack of consistent definitions of nonbank investor groups across the economies, we are unable to estimate panel regressions. As such, we focus on the individual country-investor group regressions. Key coefficients are reported in Tables 5.3 and 5.4, with full results in Appendix A5.

Our results point to substantial heterogeneity in the domestic nonbank subgroups across economies. In the US, over the full period the "household" sector is the most important offset to changes in central bank holdings. Moreover, while demand from the "household" sector substitutes for around 50% of the change in the Fed's balance sheet across all periods on average, this rises substantially during QT episodes. Indeed, the results suggest that "household" holdings of government debt securities offset 94% of QT1 (51% across all periods plus the 43% increase during QT1, though the latter is not statistically significant) and 120% of QT2 (51% across all periods plus the 69% increase during QT2).

However, it is important to note that the "household" sector is the residual sector in the US Flow of Funds data and there is considerable uncertainty regarding the types of investors within this category that contributed to this rise in Treasury holdings during QT. Of note, the household sector includes levered investors, such as hedge funds[74]. Analysis from the Fed based on the SEC Form PF data suggests that hedge funds' holdings of Treasury securities were about two-thirds of the "household" sector's US Treasury holdings at end-2019.[75] The overall US Treasury

[73] Data sources for the four countries can be found at: US (here), UK (here), Canada (here), and Australia (here).
[74] Levered funds includes not only hedge funds, but also other types of money managers, such as commodity trading advisors.
[75] Banegas, Monin, and Petrasek (2021) finds that qualifying hedge funds (those with at least $500mn of assets under management and which account for roughly 80% of gross hedge fund assets) held more than $1tn of Treasury securities at end 2019. This compares to $1.59tn for the household and non-profit institution sector as a whole.

exposure for hedge funds, including long and short positions across cash securities and derivatives, is considerably larger and has risen more substantially over time.[76]

Table 5.3
Domestic nonbanks: Significance of change in central bank holdings across all time periods ($\beta_{i,j,1}$)

	Households	Broker & dealers	Pension	Insurance	Investment funds	State and Local	Others
US	-0.51***	-0.10**	-0.19*	0.00	-0.06	0.07	0.00
UK	0.00			-0.22***	-0.45***	0.00	0.00
CA	-0.07***	-0.06***		-0.46***	0.11	-0.06	-0.13***
AU	0.00		-0.08**	-0.21*	-0.19**		-0.02

Note: Table displays the coefficients on the central bank share from equation 5.1 using country-specific data sources, which are presented in the text. Cells are color coded to show relative values with more negative values red and positive values green. Asterisks denote coefficient estimates that are significant at the 1% (***), 5% (**) and 10% (*) levels with the expected sign (i.e., negative).

Table 5.4
Domestic Nonbanks: Significance of Interaction Term with QT Dummy
(i.e., Additional QT Effect, $\beta_{i,j2}$)

	Households	Broker & dealers	Pension	Insurance	Investment funds	State and Local	Others
US QT	-0.61**	0.00	-0.35	-0.02	0.29	-0.12	-0.12***
US QT1	-0.43	0.01	-0.41	0.05	0.26	0.04	-0.16***
US QT2	-0.69***	-0.01	-0.31	-0.06***	0.31	-0.20*	-0.10***
UK	-0.01**			-0.37***	-1.00***	0.00	0.00
CA	0.05	0.04		0.31	-0.29	-0.19***	0.30
AU	0.00***		-0.18*	-0.18	0.09		-0.21***

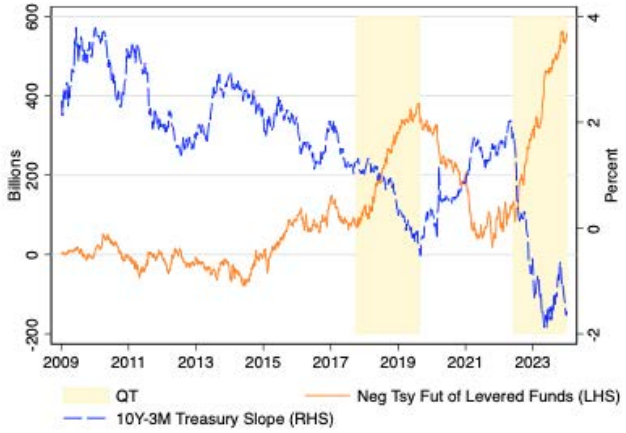
Note: Table displays the coefficients on the interaction term between the central bank share and QT dummy from equation 5.2 using country-specific data sources, which are presented in the text. Cells are color coded to show relative values with more negative values red and positive values green. Asterisks denote coefficient estimates that are significant at the 1% (***), 5% (**) and 10% (*) levels with the expected sign (i.e., negative).

Moreover, as Figure 5.2 demonstrates, according to data from the Commodity Futures Trading Commission (CFTC), levered funds' negative exposure to Treasury futures rose to record levels of close to $600 billion as of November 2023. This rise coincided with the rise in long cash Treasury positions of the U.S. "household" sector. This simultaneous large increase in the long cash

[76] Banegas et al. (2021) and Banegas and Monin (2024) show that the US Treasury exposure of qualifying hedge funds doubled from early 2018 to February 2020, with long and short exposure reaching $1.45tn and $0.94tn, respectively, before the pandemic. Technically, the "household" sector in the U.S. Flow of Funds should only include domestic hedge funds' positions, whereas foreign hedge funds' positions should be reported in the "rest of the world" category. The supplementary table for the US Flow of Funds B.101.f suggests that US domestic funds account for less than 20% of the Treasury long position by all hedge funds in Form PF published in Banegas and Monin (2024). However, the "rest of the world" position in the US Flow of Funds relies on surveys from Treasury International Capital (TIC), which may not include foreign hedge funds with large Treasury positions. Therefore, the "household" sector, as a residual sector, may also include foreign hedge fund positions that are not covered by the TIC surveys.

position and the short futures position implies that a significant part of the hedge funds' Treasury holdings during QT are part of the so-called "Treasury cash-futures basis trade."[77] While QT may have contributed to these dynamics, Du, Hebert and Li (2023) argue that the main driver was a deeply inverted yield curve -- which resulted from a historically aggressive rate hike cycle.[78] Recent Fed analysis by Glicoes et al. (2024) quantifies the size of the hedge funds' Treasury cash-future basis trade and suggests that the basis trade accounted for most of the increase in Treasury issuance during QT1 and has increased by at least $317 billion since QT2.

Figure 5.2
Levered Funds Short Position in Treasury Futures vs. Yield Curve Slope



Source: Update of Du, Hébert and Li (2023)

Returning to Tables 5.3 and 5.4 on the role of different investor groups in absorbing changes in central bank securities holdings, including during QT, the results across other economies are varied. In the UK, both insurance and investment funds – a category that incorporates all financial corporations excluding monetary financial institutions and insurance and pension funds -- appear to play an important role in absorbing government securities during normal times, and this role significantly increased during QT.[79] In Canada, state and local governments appear to have increased their shares in a statistically significant way during QT (while generally not being an important offset to central bank holdings during the full period), while in Australia, pension funds and other investment groups shifted their behavior to help absorb a larger share of securities during QT by their respective central banks.

5.D. How did QT Affect Investor Behavior? A Counterfactual Exercise for the US

As a final analysis to further elucidate the impact of QT on investor shares, we conduct two counterfactual exercises for the US. For both counterfactuals we estimate the baseline regression from equation 5.1 up until the start of QT1 (defined as 2017q4). We then use this pre-QT regression to predict how each investor type within the domestic nonbank group would have adjusted their holdings during QT1 (2017q4-2019q3) and QT2 (2022q2 to 2023q3) given the observed decline in the Fed's share of securities holdings during those periods.

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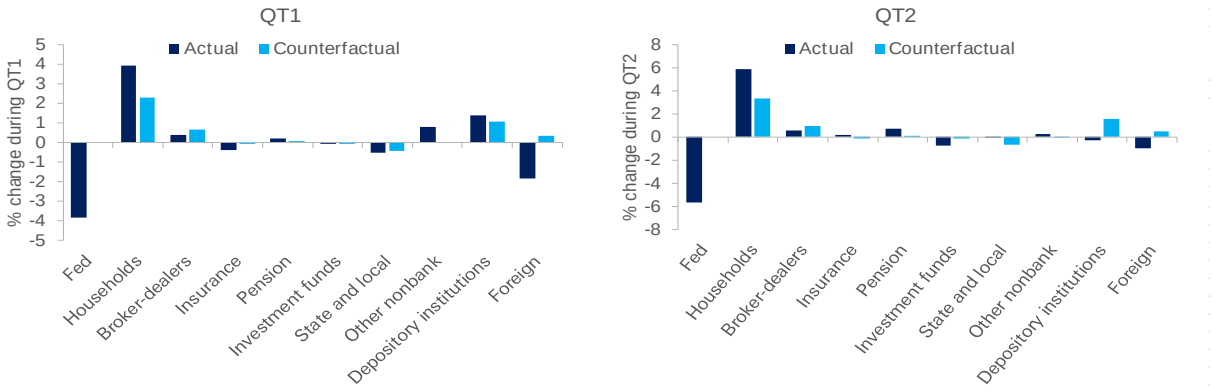
[77] This observation that long cash positions are offset by short futures positions also implies that the ultimate duration exposure does not necessarily lie with the levered investors. The question of how QT affects the distribution of duration exposure is an important question given recent focus on vulnerabilities in the nonbank financial sector. (For example, see recent work by the IMF here). We do not address this issue in this section.

[78] More specifically, by reducing demand by real money investors for longer duration government debt securities, the inverted yield curve shifted the demand for cash Treasury securities to the levered sector, including relative value hedge funds and primary dealers. The unwinding of the levered position associated with the "basis trade" built up during QT1 was viewed as a contributing factor to the stress in the U.S. Treasury market in March 2020 (BIS, 2013 and Barth, Kahn and Mann, 2023).

[79] In the UK data, hedge funds generally fall under the "overseas holdings (rest of world)" category because their asset holdings reside primarily outside of the UK.

These counterfactuals provide further evidence that QT corresponded to a shift in the historical relationships between changes in Fed securities holdings and investor behavior for some groups. For example, Figure 5.3 shows that the share of securities held by households rose by about 4 percentage points during QT1, nearly 2 percentage points more than predicted based on the pre-QT historical experience. QT2 also represented a notable break from the pre-QT relationships. During the current QT episode (QT2), households increased their share of securities holdings by roughly 6 percentage points – nearly double what would have been expected given pre-QT relationships.

Figure 5.3
US Counterfactuals for Investors During QT1 and QT2



Note: This figure compares actual changes in the shares of investors during QT1 (2017q4-2019q3) and QT2 (2022q2 to 2023q3) to counterfactuals based on the pre-QT experience. As such, the figures demonstrate the extent of the change in investor behavior during QT compared to non-QT periods.

In both QT episodes, foreign investor behavior also shifted notably from the pre-QT historical experience. Rather than increasing their shares, foreign investors reduced their shares during both QT1 and QT2. Based on the earlier regressions using the IMF data, this appears to be driven primarily by foreign official and foreign nonbank investors. Although most of the coefficients measuring changes in the role of foreign investors during QT were not statistically significant, Table 5.2 suggests securities holdings for these investor groups began to co-move more positively with the central bank during QT. This break in the historical relationship, however, could be explained by other characteristics of the tightening cycle that occurred at the same time as QT; for example, the tightening in US monetary policy could have motivated foreign officials to sell US Treasury securities to support domestic currencies against depreciation pressures.

Finally, it is worth highlighting the changes in the role of domestic depository institutions in the US, which reduced their share of securities holdings during QT2 instead of increasing them as predicted by regressions over the pre-QT period. This divergence was likely due to the constraints US banks faced on purchasing securities due to substantial unrealized losses on securities portfolios as interest rates unexpectedly surged during 2022 and 2023.

5.E. Summary

This section leverages data from the IMF and country-specific sources to assess whether holdings of government securities across investor groups respond differently during QT episodes than non-QT periods. Panel regressions using IMF data find some evidence of these changes in behavior across our sample of economies. In particular, nonbank domestic investors' securities holdings are more sensitive to changes in central bank holdings during QT periods, and these investors play an important role in absorbing the drawdown in central bank balance sheets. In the US, we find evidence that this change in behavior for domestic nonbanks was stronger for QT2 than QT1. Evidence for changes in the behavior of other investor types during QT is more heterogeneous across economies, although foreigners (including foreign central banks) have also played an important role in absorbing reductions in central bank holdings in some countries.

Using country-level data to conduct a deep-dive into the domestic nonbank sector, we find that households (a category that includes hedge funds) have been a particularly important replacement for the Fed's security holdings in the US during QT, especially during QT2. This heightened sensitivity of households / hedge funds during QT2, however, was likely exacerbated by factors related to the aggressive tightening of the overall monetary policy stance (and especially policy interest rates) during this period. For example, the deeply inverted yield curve appears to have decreased the demand for government securities by real money investors, while increasing demand for institutions motivated by the Treasury basis trade.

While these results suggest changes in investor demand for government securities during QT episodes, it is important to reiterate caution against a causal interpretation of our findings. In all cases outside of the US, the QT results rely on a single QT period that occurred over less than two years and which coincided with an aggressive tightening of monetary policy and rebound in economic activity. Economic and financial developments over this period likely also contributed to the shifts in the historical relationships among investor shares and influenced the patterns documented above. Similarly, the estimates of "normal" relationships between changes in the share of central bank securities holdings and the shares held by other investor groups are identified largely from patterns during QE after the 2008 financial crisis; this historic period was also subject to unusual economic and financial developments, including interest rates around zero and very flat yield curves. These "historic" relationships may not be a "normal" baseline.

6. Conclusions

This paper addresses four sets of questions, drawing on the experience of the seven advanced economies that have embarked on QT programs (Australia, Canada, Euro area, New Zealand, Sweden, the UK and US). First, how have central banks approached QT—in terms of their strategy, communication, and progress to date? Second, what is the impact of announcing different types of QT programs on government bond yields and a range of other market variables? Third, what are the effects of implementing QT—through both passive roll-off of

maturing securities as well as active bond sales? Finally, who steps in to buy securities when central banks reduce their asset holdings?

The results suggest that QT programs have been successful so far. Central banks have made meaningful progress in unwinding their securities holdings, with only a very modest tightening in financial conditions and no meaningful disruption to market functioning. More specifically, the announcements of QT programs have corresponded to a modest and statistically significant increase in government bond yields (for maturities of a year and longer), and potentially a decline in corporate bond returns and the government bond convenience yield. Active QT has larger effects on yields, particularly at longer horizons, and appears to work primarily by steepening the yield curve. Passive QT has more muted effects, primarily on short-term yields, and may work mainly by signaling a stronger central bank commitment to tighter monetary policy. When countries implement QT (either through passive roll-off or active bond sales), this corresponds to a modest rise in overnight funding spreads and a fall in the convenience yield of government bonds, but does not otherwise significantly affect the pricing and market liquidity of government debt securities. As central banks have reduced their securities holdings, domestic nonbanks have largely stepped in to compensate for these shifts in demand.

Overall, the results suggest that QT programs have been working as central banks intended. They are largely "in the background" and not seen as the active tool for adjusting monetary policy, but their effects have provided a small degree of support in central banks' efforts to tighten financial conditions. The effects of QT (so far) are much less than the reverse of the effects of the QE programs launched during periods of market stress (albeit only modestly less than the effects of the limited number of QE programs launched during less volatile periods). These lessons were not clear before 2020; there was only one meaningful QT experience (2017-2019 in the US) from which to learn. Looking ahead, although QT has been smooth to date, frictions could increase in the future so that QT quickly evolves from watching "paint dry" into more like watching "water boil." With this caveat, the cross-country insights from this paper should provide central banks with more information to design programs to unwind any asset purchases in the future.

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Appendices

Appendix A1
Data Appendix

Central bank balance sheet and QT dates

Country	Central bank holdings of government bonds	Central bank holdings of all securities	Other central bank balance sheet items	Active and passive QT implementation dates and active QT securities
Australia	Holdings of all Australian government securities Source: RBA Table A3.1 (link)	Holdings of all Australian government bonds and semis Source: RBA Table A3.1 (link)	RBA balance sheet Source: RBA Table A1 (link)	Passive QT dates implied from RBA's holdings Source: RBA Table A3.1 (link)
Canada	Holdings of all Canadian government securities Source: BOC (link)	Holdings of all Canadian government securities (bills, bonds, inflation linked bonds) from the BOC balance sheet Source: BOC (link)	BOC weekly balance sheet Source: BOC (link)	Passive QT dates implied from BOC holdings Source: BOC
Euro area	PSPP and PEPP Source: ECB (PSPP and PEPP)	Holdings of securities issued by euro-area residents Source: ECB (link)	Eurosystem consolidated statement Source: ECB (link)	Not available
New Zealand	"Nominal bonds held by reserve bank" + "Inflation indexed bonds held by reserve bank" + "Treasury bills held by reserve bank Source: RBNZ (link)	New Zealand Government Securities + Crown Indemnity for LSAP Programme Source: RBNZ (link)	RBNZ balance sheet Source: RBNZ (link)	Active QT dates and QT securities implied from "History - Sale of New Zealand Government Securities to New Zealand Debt Management Office" Source: RBNZ (RBNZ)

Sweden	Holdings of government bonds and bills Source: Riksbank (link)	Securities to residents inside Sweden denominated in Swedish kronor Riksbank (link)	Riksbank Assets and Liability Weekly Reports Source: Riksbank (link)	Active QT dates and QT securities from "List of transactions for government bonds" Source: Riksbank (link)
UK	Constructed from the history of BOE gilt purchases and sales Source: BOE (link)	Loan to the APF facility minus the TFS balance prior to January 19, 2016 Source: BOE (link)	BOE Weekly Report Source: BOE (link)	Active and passive QT dates and active QT securities implied from the history of gilt securities purchased and sold by the BOE Source: BOE (link)
US	Treasury securities held by the Fed Source: FRED (link)	all securities holdings held by the Fed Source: FRED (link)	Federal Reserve H.4.1. Source: FRED (link)	Passive QT dates implied from SOMA bids accepted and maturing amounts from Treasury auction results Source: Treasury Direct (link)

Other Variables

Country	Government bond market outstanding	Government bond auction bid-to-coverage	GDP	All other financial variables
Australia	Haver	Australian Office of Financial Management (link)	Haver	Bloomberg
Canada	Haver	BOC (link)	Haver	Bloomberg
Euro area	Haver	Not included in the analysis	Haver	Bloomberg
New Zealand	Haver	Debt Management Office (link)	Haver	Bloomberg
Sweden	Statistics Sweden (link)	Swedish National Debt Office (link)	Haver	Bloomberg
UK	Haver	U.K. debt management office (link)	Haver	Bloomberg
US	Haver	Treasury Direct (link)	Haver	Bloomberg

Appendix A2
Timeline of QT Related News and Activity in the "QT G7"

AUSTRALIA	
Preliminary Discussions	**02/01/2022*:** Announced would "cease further purchases under the bond purchase program, with the final purchases to take place on 10 February." This included opening the door to passive QT: "will consider the issue of the reinvestment of the proceeds of future bond maturities at its meeting in May." Link
Main Announcements and News	**05/03/2022*:** Announced the **start of passive QT** for government bonds based on balance sheet roll-off. No plans for active QT. This announcement occurred at the time of the first rate hike. Link. **05/02/2023:*** Announced would **continue passive QT** and **opened door to possibility of active QT** in the future, but no details on the date of any decision. Link
Wind Down News	NA
Current QT strategy and progress	Currently reducing portfolio through passive run-off of government bonds. Have opened door to starting active QT in the future.
Peak size/holdings	**Balance sheet peak size and composition:** AUS$281 bn in federal, state and territory government bonds in Feb. 2022. Comprised of: AUS$224 bn in Australian govt debt and AUS$57bn of state and territory govt debt (semis). **Timing:** Stopped net new purchases in Feb. 2022. First increase in the policy rate in May 2022. Passive QT began in May 2022. Link to program information on RBA website. Link to speech by Bullock.
Security-level information	Link to security information

CANADA	
Preliminary Discussions	**03/03/2022*:** Speech by Governor Macklem foreshadowing QT: "With the decision to raise the policy rate, ending reinvestment and moving to QT would be a natural next step." He clarified that this would involve runoff of maturing bonds and not active sales, but did not specify a start date. Also highlighted the shorter average term to maturity of BoC holdings relative to those of other central banks, with "roughly 40% of bond holdings maturing within the next two years. This suggests that, other things being equal, our balance sheet would shrink relatively quickly." Link. **03/25/2022*:** Speech by Deputy Governor Kozicki's provided further information on the likely start to QT: "….in early March…We also said that we will be considering when to begin to allow the Bank's holdings of Government of Canada bonds to shrink—a process known as quantitative tightening, or QT…. I expect the pace and magnitude of interest rate increases and the start of QT to be active parts of our deliberations at our next decision in April." Link.
Main Announcements and News	**04/13/2022*: Announced passive QT** by ending reinvestments in its asset purchase program, effective as of April 25, 2022. (Link) Also provided additional implementation details and stated that was not considering selling bonds (i.e., active QT). Link
Wind Down News	**03/28/2023:** Speech by Deputy Governor Gravelle said that **QT program will likely end** when settlement balances have reached a range of C$20bn – C$60bn (about 1%-2% of GDP). This "will likely occur sometime around the end of 2024 or the first half of 2025." After that, the BoC will start buying assets again as part of regular balance sheet management. Link
Current QT strategy and progress	Currently reducing portfolio through passive run-off of government bonds. No discussion of active QT. The portfolio has a relatively short average maturity, so that roughly 40% of the holdings will mature within the first two years of QT. Announced parameters to end QT (likely at end-2024/early-2025). Link to details on purchase operations.
Peak size/holdings	**Balance sheet peak size and composition:** C$435billion in aggregate holdings in Dec 2021. Primarily Government of Canada bonds. Also small allocation to Canada Mortgage Bond securities <10 bn). Emergency purchase programs also included option to purchase commercial paper, banker's acceptances, provincial money market instruments, provincial bonds (up to C$50bn) and corporate bonds (up to C$10bn), but none of these are shown on the register of BoC holdings. **Timing:** Stopped net new purchases in October 2021. First increase in the policy rate in March 2022. Passive QT began in April 2022. Link to review of Bank of Canada's market operations.

Security-level information	Link to security level information.
ECB	
Preliminary Discussions	**10/27/2022*:** President Lagarde prepared the ground in the press conference by stating: (1) the Governing Council had discussed beginning QT, specifically "the reduction of the APP monetary portfolio", (2) the key principles of QT would be "discussed and decided" in December, and (3) any decision to implement QT would be taken at some point after that. Note that the subsequent QT announcements and implementation occurred faster than generally expected. Link
Main Announcements and News	**12/15/2022*:** Announced APP reinvestments would be reduced by €15bn per month on average (i.e., **partial, passive QT**) from March 2023 until the end of Q2 2023 and then "its subsequent pace will be determined over time". This was equivalent to a 50% reduction in reinvestments over that period. Detailed parameters would be announced in February. Assets held in PEPP will continue to be rolled over "until at least the end of 2024." Link. **02/02/2023*:** Announced modalities for the €15bn per month reduction in APP reinvestments announced in December and beginning in March. The program would last until the end of June 2023, and the subsequent pace of portfolio reduction would be determined over time. Partial reinvestments would be conducted proportionally to the share of redemptions across each constituent programme. Will also tilt reinvestments in corporate bonds to account for climate performance. Link. **05/04/2023*:** Announced that **expected** to discontinue reinvestments under the APP in July 2023 (i.e., **full passive QT** that allows all maturing assets to roll-off). Link **06/15/2023***: **Announced discontinuation of APP reinvestments** as of July 2023 (i.e. **passive QT**), equivalent to reducing reinvestments by €25-30bn a month on average over the next 12 months/for the foreseeable future.
Wind Down News	NA
Current QT strategy and progress	Passive QT of APP. No announcement of active sales. Link to information on modalities. PEPP continues full reinvestment and acts as an anti-fragmentation tool.
Peak size/holdings	**Balance sheet peak size and composition:** Roughly €3.4 trillion in the Eurosystem Asset Purchase Portfolio (APP). The APP is about 60% of QE purchases, with the PEPP about 40%. The APP consists of: PSPP (public sector purchase programme), CSPP (corporate securities purchase programme), CBPP (covered bond purchase programme and ABSPP (asset backed securities purchase programme). The PSPP is by far the largest sub-portfolio.

	Timing: Stopped net new purchases in June 2022. First increase in the policy rate in July 2022. Passive QT for part of expiring securities began in March 2023. Pace of passive QT accelerated for all expiring securities in APP starting in July 2023. Overview of APP program
Security-level information	Link to security level information for the APP. Link to security-level information for the PEPP.
NEW ZEALAND	
Preliminary Discussions	NA
Main Announcements and News	**02/23/22*:** Announced **passive QT** ("not to reinvest the proceeds of any upcoming bond maturities") and **active sales of Government bonds** (including inflation-indexed) back to the NZDM (Treasury) **at a rate of NZ$5 billion** per fiscal year, commencing in July. Local Government Funding Agency Bonds would be held to maturity ("as the holdings of these bonds are relatively small").
Wind Down News	NA
Current QT strategy and progress	Passive QT and active sales (back to NZDM) at a rate of NZ$5 billion per fiscal year for government bonds. No QT for small holdings of local government bonds.
Peak size/holdings	**Balance sheet peak size and composition:** NZ$55 bn in government and Local Government Funding Agency Bonds (LGFA) bonds. This is comprised of NZ$53 bn in govt debt and NZ$1.7bn of LGFAs. **Timing:** Stopped net new purchases in July 2021 (before reaching potential envelope of NZ$100bn). First increase in the policy rate in Oct. 2021. Passive and active QT began in Feb 2022. Link to program information on RBZ website.
Security-level information	Link to security-level information.

SWEDEN	
Preliminary Discussions	NA
Main Announcements and News	**04/24/2019*: Announced partial, passive QT.** The automatic decision to reinvest funds and redemptions from maturing assets was revoked; instead, the central bank would make decisions on total purchases for certain periods. A majority of the Executive Board also decided that the Riksbank would purchase government bonds for a nominal amount of SEK 45 billion over the period July 2019 to December 2020, equivalent to about half of the payments from maturities and coupons that the Riksbank would receive during that period. This start to QT was only in place a short time as asset purchases were restarted in response to the pandemic in 2020. Link **04/28/2022*:** Announced reduction in pace of gross asset purchases from July 1-Dec 31, 2022, so that asset holdings would start to decrease (i.e., **partial passive QT**). Would purchase SEK 12bn each of government bonds, municipal bonds, and covered bonds, and SEK 1bn of corporate bonds. For comparison, the amount of maturing bonds over this period is SEK 46.6bn. Would also cease purchasing Treasuries Bills as of April 28. Link for announcement. Link for details. **06/30/2022*: Accelerated pace of passive QT** (compared to April announcement) that would occur from July 1-Dec 31. Reduced gross bond purchases by about half (relative to April announcement) to SEK 18.5 bn, consisting of SEK 6bn each of government, municipal and covered bonds and SEK 500mn of corporate bonds. Link for announcement. Will also take into account climate considerations for corporate bond reinvestments. Link to details. **02/09/2023*: Announced active sales** for government bonds with longer maturities at a rate of SEK 3.5bn/month (SEK 3bn nominal government bonds and SEK 500mn inflation-linked government bonds) starting in April (excluding July and August). This came as a surprise and occurred at the same time as a 50bp hike (also a surprise). No plans to sell holdings of non-government bonds. Link to announcement. Link to details. **06/29/2023*: Announced accelerated pace for active sales** of government bonds, increase monthly sales to SEK 5bn/month (SEK 4.2bn nominal government bonds and SEK 800mn inflation-linked government bonds) starting in September. Reiterated no plans to sell holdings of non-government bonds. Link to announcement. Link to details.
Wind Down News	NA
Current QT strategy and progress	Active sales of SEK 5bn/month of government bonds. Passive QT for non-government bonds (but no plans for active sales).

Peak size/holdings	**Balance sheet peak size and composition:** SEK 972bn in June 2022. This is comprised of: SEK 405bn of government bonds; SEK 124 bn municipal bonds; SEK 413bn in covered bonds; SEK 12bn in corporate bonds; and SEK 18bn of treasury bills. **Timing:** Stopped net new purchases in Dec 2021. First increase in the policy rate in May 2022. Passive QT began in July 2022 (with the pace initially announced in April accelerated in June). Active sales began in April 2023 and pace accelerated in Sept. 2023. Link to program information on Riksbank website.
Security-level information	Link to security level information.
UNITED KINGDOM	
Preliminary Discussions	**08/05/2021*:** Confirmed guiding principles for balance sheet reduction. Revised thresholds (from June 2018) when the MPC would start or consider QT. MPC would **commence passive QT when Bank Rate reached 0.5%,** and would **consider active sales when Bank Rate reached 1%**. Link. **07/19/2023*:** Speech by Ramsden suggesting could **increase pace of active gilt sales** at next annual review. Link. **08/03/2023*:** Reiterated key points of Ramsden speech (above). Would announce new parameters at its Sept. 2024 meeting on the target for gilt stock reduction over the 12-months starting in Oct. Link.
Main Announcements and News	**02/03/2022*:** Raised rates to 0.50% and **announced passive QT** ("cease to reinvest any future maturities falling due") **for gilts and corporate bonds**. **Also announced intent for active QE for corporate bonds**; will "initiate a programme of corporate bond sales to be completed no earlier than towards the end of 2023 that should unwind fully the stock of corporate bond purchases", details of which would be announced in 3 months. Link. **05/05/2022***: Announced "would consider beginning the process of selling UK government bonds" (i.e., **active gilt** sales) and asked Bank staff to work on a strategy, to be provided at its August meeting. **Also announced details for active corporate bond sales**, starting in September 2022. Link. Market notice details. **08/04/2022*:** Set out **principles for active gilt sales**, which were "provisionally minded to commence… shortly after its Sept policy meeting, subject to economic and market conditions…" Would vote on details at Sept. MPC meeting, but judged that "starting in September, a reduction in the stock of purchased gilts held in the APF of around £80 was likely to

	be appropriate...would imply a sales programme of around £10bn per quarter." "For following years, the MPC intended to set an amount for the reduction in the stock of purchases gilts over the subsequent twelve-month period, as part of an annual review." Link. Provisional market notice on gilt sales. **08/18/2022:** Market notice on details of **active corporate bond** sales. Link. **09/01/2022*:** Market notice with details on **active gilt** sales. Link. **09/22/2022**: Voted on and approved plan for **active gilt sales** as outline in August meeting, which would commence in September. Announcement link. Market notice details. **10/20/2022*: Announced start of active gilt sales** would now occur on 11/01/2022 (after short delay). Link. **12/15/2022:** Announced possibility of completing roll-off of portfolio of **corporate bonds earlier than previously expected**. Link. **09/21/2023***: Announced details on QT for the year starting in October. Would accelerate overall pace of balance sheet reduction to £100bn/year; the pace of gilt sales would be broadly unchanged relative to the previous year, given some increase in APF gilt maturities. Link.
Wind Down News	**09/09/2022:** Announced would push back auction sale of corporate bonds by one week to Sept 27 (Link) and stand ready to conduct corporate bond buybacks during specified execution windows from the week beginning 24 October (Link) **09/28/2022: Postponed start of gilt sales** "in light of the dysfunctional market conditions at that time"—around the mini-budget/LDI crisis. The first gilt sales operation occurred on 11/1/2022. Link. **10/11/2022: Temporarily paused corporate bond sales** for two weeks. Sales restarted on 10/25/2022. Link. **06/06/2023:** Confirmed that corporate bond sales program is concluding. Have reduced holdings by 95%, with remaining very short maturity bonds to be held until maturing fully by April 5, 2024. Link.
Current QT strategy and progress	Have almost fully wound down corporate bond holdings (to £0.8bn as of 08/02/23), with remaining very short maturity bonds to be held until maturing fully by April 5, 2024 Currently reducing gilt portfolio through passive run-off and active sales. Amount varies each month as roll-off is not evenly spaced and chunky. Amount of active sales adjusted annually.

Peak size/holdings	**Balance sheet peak size and composition:** £895 billion in UK government and corporate bonds. This is comprised of £875 gilts and £20bn corporate bonds (sterling non-financial investment-grade). **Timing:** Stopped net new purchases in Dec 2021. First increase in the policy rate in Dec 2021. Passive QT began in Feb. 2022. Active sales of corporate bonds began on Sept 2022 and of gilts in Nov. 2022 Link for QE program information and link for QT information. Link to speech by Deputy Governor Ramsden.
Security-level information	Link to security level information.
UNITED STATES	
Preliminary Discussions	**1st Stage of QT (2014-2019)** **05/21/2014:** Minutes of April meeting describe a very broad discussion of options for monetary policy normalization and request for more analysis to continue discussions and begin planning**.** Link **07/09/2014:** Minutes from June meeting state that FOMC participants "discussed the appropriate time for making a change to the Committee's policy of rolling over maturing" bonds in the portfolio, **"**with most of these participants preferring to end them after liftoff." Discussed intent to develop and communicate plans for normalization and review at upcoming meetings. Link **08/20/2014:** Minutes from July meeting provide more information on likely tenets of balance sheet normalization, including that a majority of participants **"**supported reducing or ending re- investment sometime after the first increase in the target range for the federal funds rate…" and "continued to anticipate that the Committee would not sell MBS, except perhaps to eliminate residual holdings" Link **09/17/2014:** FOMC releases a document on *Policy Normalization Principles and Plans,* laying out general principles but little detail on dates or quantities. "The Committee expects to cease or commence phasing out reinvestments after it begins increasing the target range for the federal funds rate…", i.e. **passive QT.** States "does not anticipate selling MBS. Link

	2nd stage of QT (2021-present) **12/15/21*:** Announced accelerated pace of tapering (doubling monthly reductions) and in press conference Powell commented that although the FOMC had not yet made decisions on the medium-term trajectory of the balance sheet, the same conditions that argued for a condensed timeline for rate hikes **could also imply an earlier start to passive QT**. Link **01/26/22*:** Laid the **groundwork for QT** by releasing a statement of general Principles on balance sheet reduction, which did not include details but suggested it would be appropriate to begin this year. In the press conference, Powell highlighted that it could take several meetings to work out the details but that differences in the economy allowed for QT to proceed "sooner" and "faster" than the previous experience. Link. **02/16/22***: Minutes stated that the "current economic and financial conditions would likely warrant a **faster pace** of balance sheet runoff than during the period of balance sheet reduction from 2017 to 2019…." and "a significant reduction in the size of the balance sheet would likely be appropriate." Link
Main Announcements and News	**1st Stage of QT (2014-2019)** **04/05/2017*:** Minutes from March meeting include lengthy discussion of options for balance sheet normalization, confirm 2014 principles and signal **passive QT** would start "later this year." Link **06/14/2017*:** Announced expectation "to begin implementing a balance sheet normalization program this year…by decreasing reinvestment of principal payments…" (i.e., **passive QT**). Link. Provided **details on magnitudes** in an "Addendum to the Policy Normalization Principles and Plans" that these would occur through gradually rising caps on the reinvestment of principles repayments. For maturing Treasury securities, the cap would be "$6 billion per month initially and will increase in steps of $6 billion at three-month intervals over 12 months until it reaches $30 billion per month." For agency debt and MBS, the cap would be "$4 billion per month initially and will increase in steps of $4 billion at three-month intervals over 12 months until it reaches $20 billion per month." This pace and magnitude of QT for Treasuries was larger than expected, but for MBS was smaller than expected. (See D'Amico and Seida, 2022). June 2017 Survey of Primary Dealers **09/20/2017*:** Announced **passive QT (with caps) will begin next month** according to the plan previously laid out. "In October, the Committee will initiate the balance sheet normalization program described in the June 2017 Addendum to the Committee's Policy Normalization Principles and Plans." Link

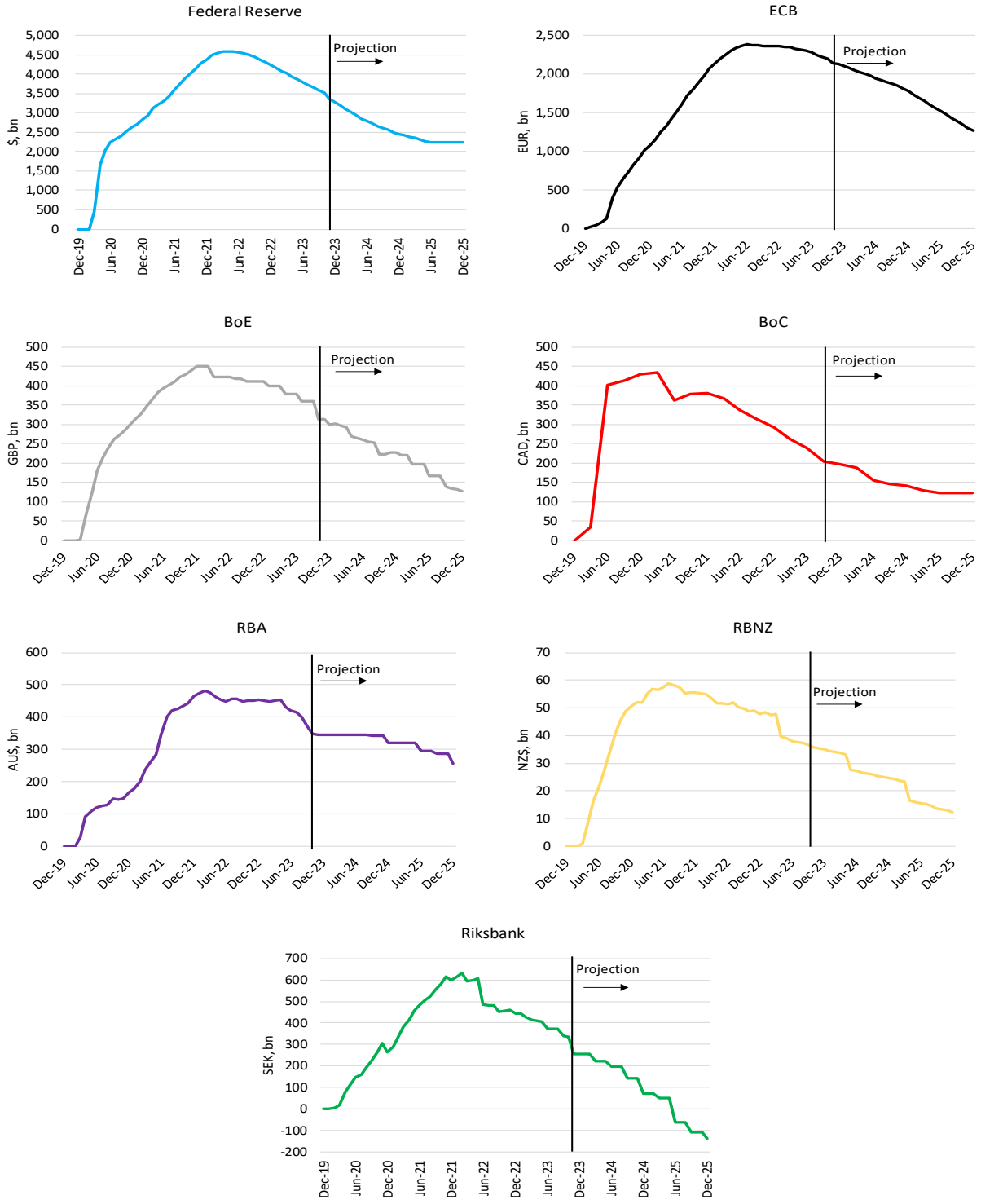
	2nd stage of QT (2021-present) **03/16/2022***: FOMC meeting statement noted that reduction in the balance sheet would begin "at a **coming meeting**" (link) and Powell noted that more details would be provided in the Minutes. The minutes (released 4/06/22) included **a detailed discussion of QT**, confirming the principles from the last meeting, but with more information on likely magnitudes ("monthly caps of about $60 billion for Treasury securities and about $35 billion for agency MBS would likely be appropriate… phased in over a period of three months or modestly longer if market conditions warrant") and timing ("as early as after the conclusion of its upcoming meeting in May". Link **04/05/22*:** Speech by Brainard suggesting QT could occur more rapidly than previously expected, starting at the May meeting, and with a larger caps and a faster phase-in than occurred in 2017-2019. Also suggested QT would "contribute to monetary policy tightening over and above the expected increases in the policy rate. Link **05/04/22*:** Announced partial, passive QT would begin on June 1, along with parameters in "Plans for Reducing the Size of the Federal Reserves' Balance Sheet". The initial cap was $30bn for Treasuries and $17.5bn for MBS per month, with a 3-month phase in period, eventually increasing to $60bn in Treasuries and $35bn in MBS in September and then staying at this pace. Holdings of T-bills were used to "top up" when Treasury securities fell short of the cap. Link
Wind Down News	**1st Stage of QT (2017-2019)** **03/20/2019: Announced phasing out of QT earlier than expected and implying a larger terminal size of the balance sheet**. (See D'Amico and Seida, 2022). More specifically, released "Balance Sheet Normalization Principles and Plans" which decreased redemption caps starting in May (versus expectation of September) and ending QT in September, 2019 (versus expectation of 2019Q4). (See March 2019 Survey of Primary Dealers) More specifically, would "slow the reduction of its holdings of Treasury securities by reducing the cap on monthly redemptions from the current level of $30 billion to $15 billion beginning in May 2019.." and "conclude the reduction of its aggregate securities holdings in the System Open Market Account (SOMA) at the end of September 2019." MBS holdings would "decline, consistent with the aim of holding primarily Treasury securities in the longer run," but "Principal payments from agency debt and agency MBS below the $20 billion maximum will initially be invested in Treasury securities across a range of maturities to roughly match the maturity composition of Treasury securities outstanding" **2nd stage of QT (2021-present)** NA

Current QT strategy and progress	Passive QT with caps ($60bn for Treasuries and $35bn for MBS) setting a maximum amount of roll-off each month. Cap is usually not binding for MBS.
Peak size/holdings	**1st Stage of QT (2014-2019)** **Peak balance sheet size and composition:** $4.4 tn in Oct. 2017 at start of QT, including about $2.5tn in Treasuries and $1.8bn in MBS/ABS. Reduced to $3.7trillion when QT ended. Total reduction in balance sheet was $0.7 trillion. **Timing:** Stopped net new purchases in Oct. 2014. First increase in the policy rate in Dec 2015. Passive QT began in Oct. 2017. **2nd stage of QT (2021-present)** **Peak balance sheet size and composition:** $8.9 tn in April 2022, including $5.8tn of US Treasury securities and $2.7tn of ABS/MBS. Note that the balance sheet increased in 2023Q1 as part of the emergency lending program to relieve the banking stress **Timing:** Stopped net new purchases in March 2022. First increase in the policy rate in March 2022. Passive QT began in June 2022. Link to FOMC document with a chronological account of decisions, discussions, and communications on policy normalization, including w.r.t the balance sheet.
Security-level information	Link to information on Federal Reserve's balance sheet.

Notes: Table lists key dates and information related to QT in the sample of seven economies through October 2023. Dates marked with a "*" are in the baseline sample. The timeline does not include discussions related to tapering asset purchases (unless this includes a discussion of QT). The dates listed are those announced in central bank communication and may not coincide with actual changes in the size of the balance sheet. For example, after passive QT begins, the balance sheet may not shrink until a later date when a security expires, or the balance sheet could begin to shrink before the official start of QT because other securities held on the balance sheet expire. The quantities listed for peak balance sheet size may also differ from other sources for several reasons, including whether initial holdings before the start of QE are included and whether securities purchases that were part of the Covid response but not part of the official QE program are included.

Sources: Information is from official central bank communication, based on the references included above.

Figure A2.1
Central Bank Balance Sheet Projections
(Net Increase from end-2019)



Notes: Charts show central bank balance sheet projections through end-2025 under the assumption that QT proceeds under its current parameters. For the Fed, QT is assumed to slow when reserves/GDP hits 10% and cease when this ratio reaches 9%, in line with assumption from NY Fed projections. For the Riksbank, we use projections provided in their November 2023 Monetary Policy Report (see https://www.riksbank.se/en-gb/monetary-policy/monetary-policy-report/2023/monetary-policy-report-november-2023/).

Appendix A3
Announcement Effects: QT Surprises, Sensitivity Tests and Individual Country Results

QT Surprises

One challenge with this event study methodology, and a factor that could explain these estimates of more muted effects from US QT, is that if a QT announcement is widely expected, any impact on financial variables would likely already be priced in before the event date. If so, the coefficients reported above would be biased downward and underestimate the impact of QT news (or even estimate no effect if the announcement was fully priced in). An event study would ideally only include events that were a surprise, or would estimate the impact on market prices from the earliest date when investors began to price in any potential QT-related news. This is challenging for QT events, however, as different investors may have begun to expect QT news at very different times, and extending the event window to incorporate any potential effects as investors began to price in changes in QT policy would make it impossible to identify the impact of QT (since other events would impact market prices in the interim).

In order to control for this potential bias and better estimate the impact of QT news, we categorize a subset of the QT events listed in Appendix A2 as a "surprise". This is difficult to judge in many cases, so we consult several sources. We begin by asking analysts at four major financial institutions[80] that have large research departments covering central banks to review their written reports from immediately before and after each of the QT events listed in Appendix A2 and specify whether the announcement was a surprise relative to their written predictions.[81] Next, for countries that release information on market expectations for balance sheet policy, we compare the announcements in Appendix A2 with market expectations before each event. This comparison is possible for the Federal Reserve and ECB for many of their events, and for the Bank of England for a subset of dates.[82] We do not look at market reactions to the QT-related events, as this would bias our estimates of how the news affected market pricing.

[80] The four institutions were Deutsche Bank, JPMorgan, Morgan Stanley and Vanguard. Thanks to Seth Carpenter, Mike Feroli, Fiona Greg, and Matt Luzzetti for working with their research teams to compile this data.
[81] We also collected information on how the announcement was a surprise—such as the magnitude of QT, start date, type of security included in the QT program, etc. Forecasts were generally ranges and hard to compare across analysts, so calculating the degree of surprise was difficult.
[82] Information for the US is from the Federal Reserve Bank of New York's Survey of Primary Dealers (SPD) and Survey of Market Participants. Information for the ECB is from the ECB's Survey of Monetary Analysts and information for the UK is from the BoE's Market Participants Survey. These surveys do not include information for some events in the timelines that are not central bank announcements linked to regular policy meetings, and the BoE survey asks different questions each month and does not have information to assess QT expectations in many months.

Classifying QT events as a surprise was not straightforward, and in some cases required substantial judgement. For example, the variety of details around QT announcements allows *ex post* financial analysts to classify more events as "close to expectations", even in cases when surveys of market forecasts suggest there was a meaningful surprise for a subset of investors. For some events, there is disagreement amongst the market forecasters in terms of what to expect at a central bank meeting—so the subsequent announcement was a surprise for some subset of investors, but not others. In other cases parts of an announcement were widely expected (such as the magnitude of QT), but the exact timing or type of security included was a surprise. In cases when the classification is not clear, we place more weight on formal surveys of market participants than *ex-post* assessments of individual analysts. We also use a strict bar to classify an event as a surprise—labelling any cases as "no surprise" if the surprise component is minimal or when there is no information to make the assessment (such as for countries with limited analyst coverage and no market surveys).

This (highly subjective) classification procedure generates 14 events (listed below) that are classified as a *QT Surprise*, out of the 48 events listed in Appendix A2. It is worth noting that countries that do not have regular surveys of market participants (i.e., for all central banks except the ECB and Federal Reserve) and that have less comprehensive coverage by market analysts are less likely to have an event that qualifies as a surprise as there may not be a concrete prediction of what to expect before any QT announcement.

Appendix Table A3.1
QT "Surprise" Events

Country	Date	News	Transaction	Security
Euro Area	12/15/2022	MA	P	GCA
Euro Area	5/4/2023	MA	P	GCA
New Zealand	2/23/2022	MA	A, P	G
Sweden	4/28/2022	MA	P	GS
Sweden	6/30/2022	MA	P	GS
Sweden	2/9/2023	MA	A	G
United Kingdom	8/5/2021	PD	A, P	G
United Kingdom	8/4/2022	MA	A	G
United Kingdom	7/19/2023	PD	A	G
United States	4/5/2017	MA	P	GA
United States	3/20/2019	WD	P	GA
United States	1/26/2022	PD	P	GA
United States	3/16/2022	MA	P	GA
United States	4/5/2022	MA	P	GA

Notes: See Appendix A2 for details on the QT news for each of the dates in the table. See text for discussion of what criteria are used to classify an event as a "surprise". For the type of news, MA is *Main Announcement,* PD is *Preliminary Discussion* and WD is *Wind Down* . For the transaction type, P is *Passive* QT and A is *Active* QT. For the type of security, G is *Government* , C is *Corporate* , A is *Agency/mortgage-backed* , and S is *State/municipal/territory/local* .

Next, we incorporate this definition in our baseline model by only including QT events that are a surprise. We also include two types of QT surprises: dummies for events that are announcements of new/additional QT (QT_{it}^{S}) and those that are announcements of a QT *Wind Down* ($QT_{it}^{S,WD}$):

$$\Delta y_{it} = \alpha_i + \varphi_1 QT_{it}^{S} + \varphi_2 QT_{it}^{S,WD} + \boldsymbol{\gamma News}_{it} + \varepsilon_{it} \ . \qquad \text{(A.3.1)}$$

In the sample above, the only event that is a *Wind Down Surprise* is the US announcement that it would end QT faster than expected on 03/20/19. This specification therefore only estimates the impact of Surprise QT events, and to avoid biasing estimates of the control sample of non-QT surprise dates, we exclude any dates from the control group when there was a QT announcement of any type that is not classified as a surprise.

Appendix Table A3.2
Announcement Effects of QT "Surprise" Events

Impact of "Surprise" QT Announcements on Government Bond Yields						
	Two-day Change in Yields (pp)					
	3 month	1 year	2 year	5 year	10 year	30 year
QT Surprise	-0.014	0.084**	0.066	0.067	0.073*	0.054**
	(0.021)	(0.034)	(0.040)	(0.043)	(0.041)	(0.024)
QT Wind Down Surprise	0.009***	-0.028***	-0.070***	-0.092***	-0.081***	-0.060***
	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Observations	*9,488*	*12,494*	*14,554*	*14,723*	*14,817*	*10,332*
R^2	*0.005*	*0.026*	*0.023*	*0.017*	*0.009*	*0.007*

Impact of "Surprise" QT Announcements on Other Financial Market Indicators							
	Stock index	Corp Bond	ER (US$)	FCI index	Inflation Comp. 3 year	Inflation Comp. 5 year	Convenience Yield
QT Surprise	-0.005	-0.002	-0.004*	0.034	-0.003	0.019	-0.031**
	(0.006)	(0.002)	(0.002)	(0.047)	(0.022)	(0.029)	(0.015)
QT Wind Down Surprise	0.007***	0.005***		-0.076***	0.024***	0.021***	-0.004***
	(0.000)	(0.000)		(0.002)	(0.002)	(0.002)	(0.000)
Observations	*14,224*	*12,164*	*12,833*	*14,923*	*9,661*	*11,472*	*14,512*
R^2	*0.002*	*0.010*	*0.008*	*0.021*	*0.004*	*0.003*	*0.001*

Notes: Coefficient estimates from equation 3.1, except only including the "Surprise" QT events listed in Appendix Table A3.1. All specifications continue to include controls for the *Interest Rate Surprise* and *Economic Data Surprise* variables, as well as country fixed effects. See notes to Table 3.1 and 3.2 for additional information.

Results for the impact on the 2-day change in yields at different horizons and other financial indicators are reported in Appendix Table A3.2. Surprise QT events that are new/additional QT have positive effects on yields for 1-year maturities and longer. The effects are often larger than for the pooled sample of all QT events (Figure 3.1), but more often insignificant. These *Surprise* QT events also generally have insignificant effects on other financial indicators. These larger average effects of QT announcements that are classified as a *Surprise* than our baseline results are consistent with other work indicating that event studies will understate the impact of news if it is not a surprise on the event date. The larger effects, however, could also reflect that more of the surprise events were classified as *Main Announcements,* which tend to have a larger

impact. The more significant results for the announcements that were not classified as a surprise suggests that even if QT announcements were widely expected, they still provided some news. Also, the results suggest that the one QT *Surprise* that was a *Wind Down* (the US announcement in 2019), corresponded to a reduction in yields at the 2-year horizon and longer, a significant improvement in the stock and corporate bond index, as well as an easing in financial conditions and increase in 3-year inflation compensation. Most of these effects are in the expected direction—but given there is only one observation—it is impossible to assess significance.

All in all, our estimates of the "surprise" component of QT is not precise, so any comparisons should be interpreted cautiously. With this major caveat, our baseline results may somewhat understate the impact of QT announcements on bond yields by including events that were not a surprise, and which were already at least partly incorporated in market prices. It is hard to assess the magnitude of any such bias, however, as QT announcements that appeared to be more of a surprise do not have a significantly larger impact on any of the financial variables (including government bond yields). Moreover, any such bias does not seem to be driving the estimates that QT announcements generally had small and insignificant effects on financial variables other than bond yields.

Additional Sensitivity Tests

In addition to the analysis of announcement effects in Section 3, we have also performed a number of sensitivity tests: (1) exclude QT announcements from the US or the US and UK as both have many QT events and could drive the results; (2) only include the shorter period from 2021-2023 (excluding 2014-2019); (3) utilize a broader sample of periods and events, including the periods of market turmoil (e.g., 2020 and the LDI crisis and SVB/Credit Suisse bank failures); (4) estimate the effects over one-day, one-week and four-week windows (instead of two-day windows); (5) do not include any controls for interest rate surprises or other economic news (as is often done in event studies); and (6) estimate the model without fixed effects (but either robust standard errors or errors clustered by country), or with random effects.

In each of these tests, the key results reported above are generally robust, albeit with a few noteworthy changes consistent with the evidence reported above. When we exclude the US (or the US and UK), the estimates of the impact of QT on yields are somewhat larger, consistent with the more muted impact of QT in the US. When we use one-day windows, the effects of QT announcements are generally smaller and often insignificant, consistent with arguments in earlier work that it could take more than a day for balance-sheet announcements to be incorporated in market pricing. When we use a one-week window, the coefficients have similar magnitudes (or slightly larger than in the baseline), but also larger standard errors, so that many results become insignificant. When we use four-week windows, the estimated effects on yields are much larger and usually significant, but this likely captures other changes in monetary policy over the longer windows (especially as this was a period when central banks were shifting towards tighter monetary policy). Unfortunately, event studies are not very informative for assessing whether any short-term effects persist over a longer period.

Appendix Table A3.3
Announcement Effects of Quantitative Tightening on Government Bond Yields by Economy

Coefficient Estimates for Individual QT Dummy for Each QT Event

		Two-day Change in Government Bond Yields (pp)					
Country	**Date**	**3 month**	**1 year**	**2 year**	**5 year**	**10 year**	**30 year**
Australia	02/01/22		-0.032	0.009	0.043	0.030	-0.008
Australia	05/03/22	0.088	0.427	0.287	0.248	0.255	0.267
Australia	05/02/23	0.106	0.132	0.102	0.039	0.034	0.069
Canada	03/03/22	-0.017	-0.032	-0.087	-0.152	-0.148	-0.090
Canada	03/25/22	0.038	0.117	0.206	0.181	0.113	0.026
Canada	04/13/22	0.053	0.018	0.064	0.084	0.114	0.091
EA	10/27/22	0.093	-0.083	-0.012	-0.005	-0.011	-0.031
EA	12/15/22	-0.075	0.111	0.274	0.269	0.199	0.132
EA	02/02/23	0.055	-0.035	-0.127	-0.119	-0.091	-0.001
EA	05/04/23	0.020	-0.030	-0.051	0.005	0.059	0.106
EA	06/15/23	0.068	0.111	0.104	0.073	0.021	-0.038
NewZealand	02/23/22			0.121	0.090	0.058	0.036
Sweden	04/24/19	-0.003		-0.086	-0.123	-0.135	
Sweden	04/28/22		0.417	0.193	0.217	0.181	
Sweden	06/30/22	-0.034	-0.034	-0.277	-0.338	-0.292	
Sweden	02/09/23		0.203	0.257	0.262	0.338	
Sweden	06/29/23	-0.052	-0.015	0.043	0.060	0.050	
UK	08/05/21		0.072	0.085	0.084	0.109	0.086
UK	02/03/22	0.075	0.227	0.221	0.191	0.148	0.114
UK	05/05/22		-0.151	-0.145	-0.074	0.026	0.093
UK	08/04/22	-0.006	0.096	0.125	0.151	0.138	0.129
UK	09/01/22	0.033	0.090	0.095	0.079	0.111	0.194
UK	10/20/22		0.239	0.233	0.257	0.179	0.077
UK	07/19/23	-0.108	0.000	-0.098	-0.077	-0.051	-0.056
UK	08/03/23	-0.038	-0.104	-0.099	-0.053	-0.029	0.014
UK	09/21/23	-0.002	0.013	0.019	0.020	0.056	0.048
US	05/21/14	0.000	-0.005	0.005	0.033	0.038	0.043
US	07/09/14	-0.011	-0.007	-0.057	-0.045	-0.023	-0.005
US	08/20/14	-0.021	0.016	0.030	0.045	0.001	-0.030
US	09/17/14	-0.010	0.024	0.027	0.062	0.026	-0.008
US	04/05/17	0.025	-0.003	-0.023	-0.039	-0.025	-0.017
US	06/14/17	0.001	-0.003	-0.005	-0.010	-0.040	-0.070
US	09/20/17	-0.005	-0.004	0.025	0.041	0.024	-0.018
US	12/15/21	-0.013	-0.009	-0.047	-0.073	-0.031	0.025
US	01/26/22	0.006	0.136	0.149	0.084	0.016	-0.032
US	02/16/22	-0.050	-0.083	-0.133	-0.120	-0.097	-0.076
US	03/16/22	-0.064	0.002	0.059	0.035	0.025	-0.010
US	04/05/22	0.111	0.051	0.043	0.127	0.199	0.168
US	05/04/22	-0.088	-0.076	-0.072	-0.004	0.073	0.118

Notes: Estimates of QT dummies for each QT event (β^n) in equation 3.2 predicting the two-day change in government bond yields for the maturity listed at the top. Coefficients are color coded with green indicating positive, red indicating negative, and darker colors indicating larger absolute values (scaled by the high/low for the table). Each regression includes controls for the *Interest Rate Surprise* and *Economic Data Surprise* variables over the same window as the change in yields. The QT events are listed in Appendix A2 and marked with * for the base sample. The sample excludes periods of heightened market volatility around the start of the pandemic, the LDI crisis in the UK and SVB/Credit Suisse Banking turmoil. All estimates include robust, Newey-West standard errors. Stars are not included as most coefficients are highly significant because they are estimated off one observation.

Appendix Table A3.4
Announcement Effects of Quantitative Tightening on Other Financial Indicators by Economy

Coefficient Estimates for Individual QT Dummy for Each QT Event

						Inflation Compensation		
		Stock	Corp Bond					Convenience
Country	Date	index	index	ER (US$)	FCI index	3-year	5-year	Yield
Australia	02/01/22	0.016	-0.001	0.012	0.053	0.009	0.014	-0.027
Australia	05/03/22	-0.002	-0.011	0.026	0.368	0.038	0.032	-0.184
Australia	05/02/23	-0.012	-0.003	0.002	0.031	0.049	0.038	-0.095
Canada	03/03/22	0.006	0.007	-0.007	-0.083		-0.004	0.010
Canada	03/25/22	0.001	-0.004	0.001	0.063		-0.004	-0.005
Canada	04/13/22	0.006	-0.006	0.004	0.131		-0.008	-0.016
EA	10/27/22	0.001	0.003	-0.011	-0.084	0.282	0.167	0.002
EA	12/15/22	-0.040	-0.012	-0.010	0.159	-0.153	-0.136	-0.011
EA	02/02/23	0.016	0.009	-0.017	-0.099	-0.017	0.023	0.007
EA	05/04/23	0.005	-0.001	-0.002	-0.021	0.040	0.048	-0.014
EA	06/15/23	0.004	-0.001	0.010	0.040	0.082	0.069	-0.008
NewZealand	02/23/22	-0.032	-0.003	-0.006	0.121			0.001
Sweden	04/24/19	0.010	0.003	-0.020	-0.273	-0.045	-0.029	0.023
Sweden	04/28/22	0.012	-0.004	-0.005	0.050	0.041	0.268	-0.064
Sweden	06/30/22	-0.018	0.009	-0.009	-0.132		-0.137	-0.069
Sweden	02/09/23	-0.020	-0.004	0.012	0.344	-0.082	-0.014	-0.203
Sweden	06/29/23	0.021	0.000	-0.001	-0.049	-0.003	-0.034	0.002
UK	08/05/21	-0.001	-0.007	0.000	0.091	0.056	0.039	-0.021
UK	02/03/22	-0.009	-0.024	-0.004	0.060	-0.090	-0.118	-0.020
UK	05/05/22	-0.014	-0.005	-0.022	-0.012	-0.032	-0.095	0.012
UK	08/04/22	-0.001	-0.007	-0.006	0.045	0.055	0.046	-0.005
UK	09/01/22	0.000	-0.011	-0.010	0.010	-0.353	-0.209	-0.004
UK	10/20/22	0.006	-0.010	0.008	0.050	-0.025	0.010	-0.030
UK	07/19/23	0.025	0.007	-0.012	-0.224	-0.007	0.011	-0.023
UK	08/03/23	0.000	0.001	0.003	0.009	-0.012	-0.017	0.003
UK	09/21/23	-0.014	-0.002	-0.003	0.072	0.016	-0.001	0.005
US	05/21/14	0.010			-0.008	0.045	0.049	0.000
US	07/09/14	0.000			-0.012	0.014	0.034	-0.001
US	08/20/14	0.005			-0.038	0.007	0.006	-0.008
US	09/17/14	0.005			0.011	-0.118	-0.123	-0.006
US	04/05/17	-0.002	0.001		-0.005	-0.014	0.001	-0.010
US	06/14/17	-0.005	0.003		0.026	-0.131	-0.099	0.004
US	09/20/17	-0.003	0.000		0.030	-0.027	-0.033	0.012
US	12/15/21	0.006	-0.001		-0.047	-0.021	0.024	-0.030
US	01/26/22	-0.007	-0.002		0.077	-0.047	-0.017	0.008
US	02/16/22	-0.020	0.000		0.067	-0.007	-0.040	-0.008
US	03/16/22	0.034	0.010		-0.300	0.121	0.124	0.006
US	04/05/22	-0.023	-0.013		0.238	-0.046	-0.001	-0.004
US	05/04/22	-0.008	-0.007		0.127	-0.045	0.023	-0.011

Notes: See notes to Appendix Table A3.3 for format and definitions. The colors are now scaled based on individual columns (not the whole table), except the 2 columns for inflation compensation, which are scaled as a group. The Stock and Corporate Bond indices are broad market indices. The exchange rate is relative to the US$ (with a negative valued indicating depreciation) and the Financial Conditions Index is from Goldman Sachs. Inflation compensation is measured by swaps (or breakevens if not available) at the 3- and 5-year horizons. The Convenience Yield is measured as the difference between the 10-year swap tenor and government bond yield. The indices and exchange rate are calculated as percent changes, and the other variables as change, each over two-days. All data is from Bloomberg.

Appendix A4
Implementation Effects: Additional Results

In order to construct these QT-date and QT-security dummies, we collect detailed security-level data on central bank holdings for six of the seven central banks in our sample. Other than the ECB, each of these central banks discloses security-level government bond holdings or transaction data to the public (with details in the data appendix). The ECB only discloses aggregate government bond holdings at the euro-area country level, so we are unable to infer specific QT dates for the ECB and therefore do not include the Euro area in the analysis below.

We first run the following panel regression comparing changes in government bond yields on QT dates versus on non-QT dates:

$$\Delta y_{n,i,t} = \alpha_{\mathrm{i}} + \gamma_t + \beta \times \mathrm{QT}_{\mathrm{i,t}} + \epsilon_{n,i,t}\,. \qquad \text{(A4.1)}$$

The dependent variable ($\Delta y_{n,i,t}$) is the one-day change of the *n*-year government bond yield from country *i* at time *t*, based on constant-maturity benchmark government bond yields from Bloomberg. The QT dummy ($QT_{i,t}$) is equal to 1 if there are active sales of government bonds (active QT) or if there are government bonds maturing from the central bank portfolio that are not fully rolled over (passive QT). Note that the maturity dates of the government bonds often, but not always, line up exactly with the auction dates of the new government bonds. We include country fixed effects (α_i) and date fixed effects (γ_t) as additional controls. The regression is estimated between January 2021 and December 2023.

Table A4.1
Regressions of One-Day Changes in Government Bond Yields
on the QT Implementation Date Dummies

	(1)	(2)	(3)	(4)	(5)	(6)
	3M	**1Y**	**2Y**	**5Y**	**10Y**	**30Y**
QT	-0.25	0.10	0.24	0.40	0.37	0.37
	(0.41)	(0.45)	(0.51)	(0.47)	(0.42)	(0.40)
	3M	**1Y**	**3Y**	**5Y**	**10Y**	**30Y**
Active QT	0.41	0.59	0.63	0.48	0.25	0.28
	(0.85)	(0.86)	(0.88)	(0.81)	(0.79)	(0.78)
Passive QT	-0.53	-0.11	0.08	0.37	0.42	0.41
	(0.46)	(0.52)	(0.61)	(0.56)	(0.50)	(0.45)

Notes: Panel regression results for one-day changes in government bond yields (in basis points) on QT implementation date dummy. The active QT dummy is dates on which central banks actively sell government securities. The passive QT dummy is dates on which existing central bank holdings of government bonds mature and are not fully rolled over. The QT dummy in the upper panel indicates either an active or a passive QT date. All regressions are from January 2021 through December 2023. Date and time fixed effects are included. Robust standard errors are shown in the parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table A4.1 shows the regression results. The coefficients on the QT dummy are positive except for the three-month tenor, but the magnitude is less than 0.5 basis points, and all estimates are statistically insignificant from zero. The bottom panel decomposes the QT dummy into an active QT dummy and a passive QT dummy. Again, the coefficients on these two QT dummies are all small and statistically insignificant. Therefore, we do not find evidence that the changes in government bond yields on QT dates are significantly different from non-QT dates.

We next study the differences in pricing dynamics on the active QT dates between the securities that are sold by the central bank (QT securities) with the securities that are not sold by the central bank (non-QT securities). We focus on the one-day changes in the level of the individual bond yield, and the one-day change in the spread of the individual bond yield over the fitted yield curve (Bloomberg BVAL curve) of a similar maturity. As discussed in Section 2, only three central banks have implemented active QT so far: the RBNZ, Riksbank and BoE, limiting the sample for these regressions to three countries. We include all individual nominal government bonds with historical yield information on Bloomberg, and exclude the inflation-linked bonds from our analysis.

Our main empirical specification is as follows:

$$\Delta y_{j,t} = \alpha_{\mathrm{t\ x\ mat}} + \beta \times QT\ Sec_{\mathrm{j,t}} + \epsilon_{j,t} \qquad (4.2)$$

We regress the one-day change in the yield on all nominal government bonds (or the spread over the fitted yield) on fixed effects and a QT security dummy, which indicates that security *j* is included in the sale at *t*. The fixed effects take the form of the trading date times the maturity bucket (*mat*). We use broad maturity buckets: short-term (below 7 years), medium-term (between 7 years and 20 years), and long-term (over 20 years). Therefore, the coefficient of interest β is identified from the difference in the pricing behavior between the QT securities and non-QT securities on the same trading date within the same maturity bucket. Standard errors are clustered at the trading date level.

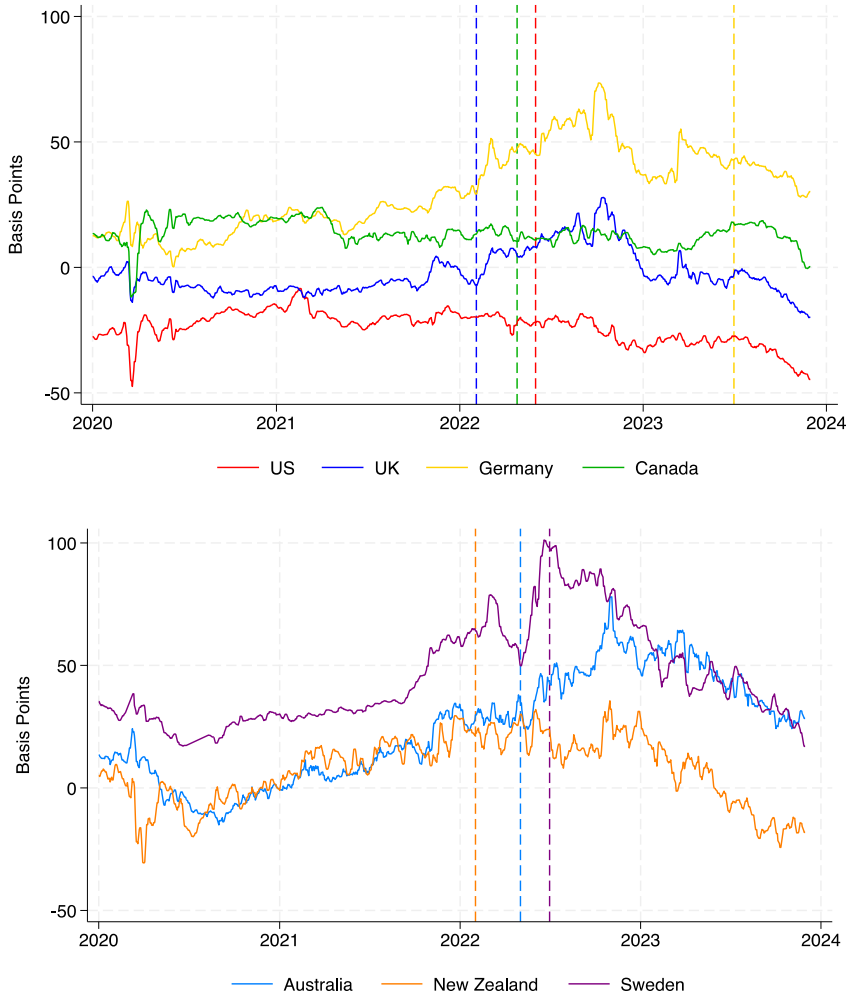
Table A4.2
Regressions of One-Day Changes in Government Bond Yields on the QT Security Dummy

	(1) SK Yield	(2) SK Spread	(3) NZ Yield	(4) NZ Spread	(5) UK Yield	(6) UK Spread
QT Security	0.16	0.38	0.16	0.35*	0.02	-0.15
	(0.36)	(0.32)	(0.27)	(0.21)	(0.09)	(0.11)

Notes: In Columns 1, 3 and 5, we regress the one-day change in the yield on all nominal government bonds in Sweden (Column 1), New Zealand (Column 3) and the UK (Column 5) on a QT security dummy, which is equal to 1 if the security i is sold by the central at date t and equals 0 if otherwise. Date and a maturity bracket fixed effects are included in the regression. Column 2, 4 and 6 perform similar regressions where the dependent variable is the one-day change in the spread between the government bond yield over the fitted Bloomberg yield curve of a similar maturity. All changes are measured in basis points. Standard errors clustered by dates are shown in the parentheses, *** p<0.01, ** p<0.05, * p<0.1.

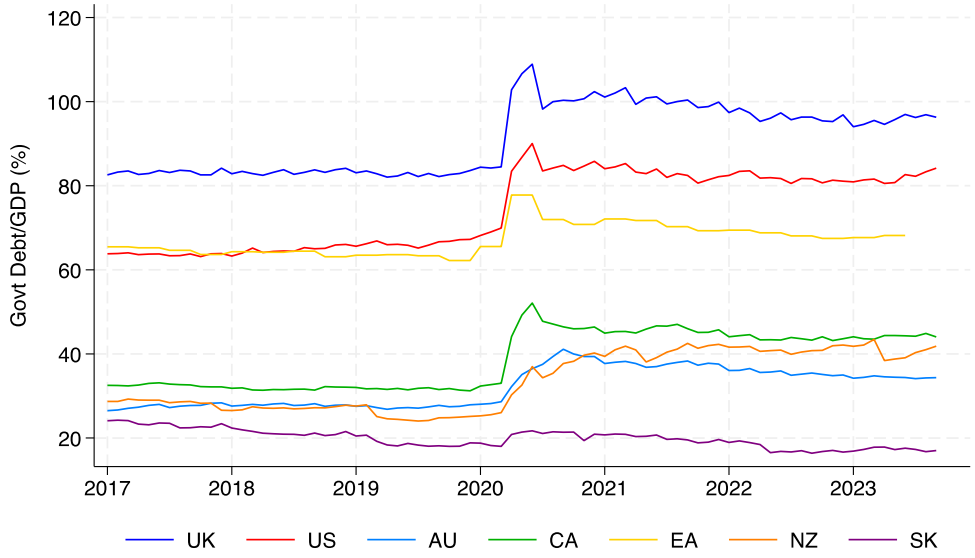
Table A4.2 shows regression results for Sweden, New Zealand and the UK. Overall, on the active QT dates, the one-day changes in the yields on securities sold by the central bank are not statistically different from those on securities not sold by the central banks. The estimated magnitudes are very similar between New Zealand and Sweden. There is some marginal significance in the case of New Zealand, indicating that the yield spread over the fitted curve increases more for the QT securities than for the non-QT securities, but the magnitude of the difference is only 0.35 basis points. In the case of the UK, we find no evidence that the QT securities experience higher yields.

Figure A4.1
Swap Spreads between the Interest Rate Swap Rate and Government Bond Yield



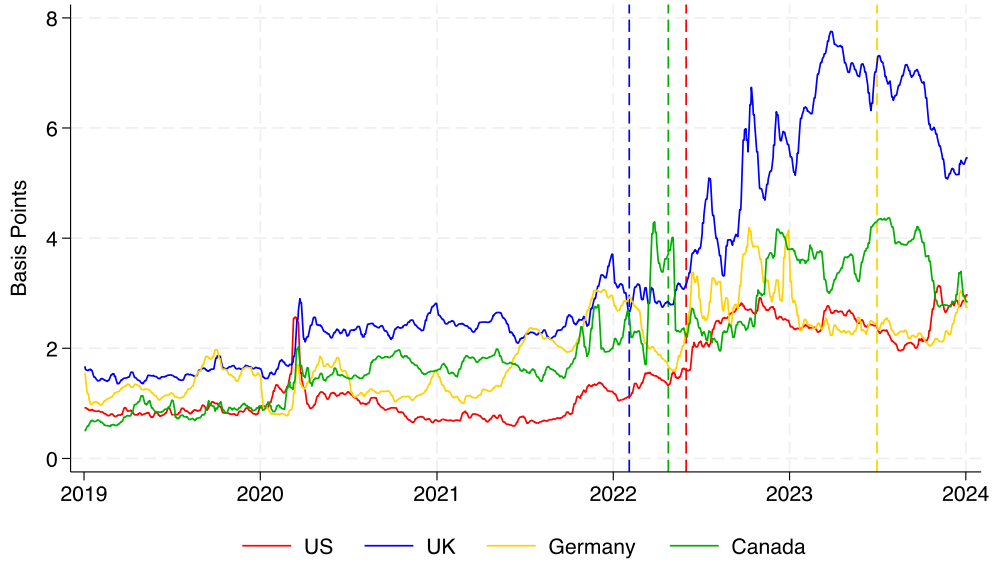
Notes: This figure plots the spread between the 10-year interest rate swap rate and the 10-year government bond yield for our sample countries since 2020. The overnight index swap rates are used for the US, UK, Germany, Canada and Sweden. The interest rate swap rates indexed to the three-month bank bill rates are used for Australia and New Zealand. All data are from Bloomberg. The vertical of the same color denotes the beginning of the post-pandemic QT in the corresponding country. One-week moving averages are plotted for all swap spreads.

Figure A4.2
Outstanding Amounts of Government Bonds as Percentage of GDP



Notes: This figure shows the outstanding debt amounts of government debt securities over GDP since 2021.

Figure A4.3
Bloomberg Government Bond Liquidity Indexes



Notes: This figure shows the Bloomberg government bond liquidity indexes for the US, UK, Germany and Canada. The index is based on the average yield curve fitting errors of individual bond yields relative to the fitted yield curve. A higher index indicates a higher average yield curve fitting error.

Appendix Table A4.3
Regression Results of Monthly Changes in Bloomberg Liquidity Index on Changes in Interest Rate Volatility and Central Bank Government Bond Holdings

	(1) US	(2) UK	(3) Germany	(4) Panel
ΔVol	0.400***	1.251***	0.860	1.041***
	(0.121)	(0.199)	(0.650)	(0.187)
ΔCB Holdings/GDP	0.0818	-0.109	0.068	-0.016
	(0.060)	(0.121)	(0.069)	(0.068)
Observations	***33***	***33***	***33***	***99***
R-squared	***0.124***	***0.392***	***0.079***	***0.236***

Notes: This table reports monthly regression results of changes in the Bloomberg government bond liquidity index on changes in the implied volatility from interest rate swaptions and changes in the central bank government bond holdings over GDP. The MOVE index (Merrill Option Volatility Estimate Index) is used as the interest rate volatility measure for the US. The implied volatility on the one-month 10-year swaption on the OIS rate is used for the UK and Germany. The sample period is between January 2021 to September 2023. Newey-West standard errors with 6-month lags are reported in the parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Appendix A5
Flow of Funds Analysis: Complete Regression Results

Table A5.1
Regression Results Using the IMF's IFS Data with and without QT Dummy

US										
	Domestic nonbanks		Foreign nonbanks		Domestic banks		Foreign banks		Foreign official	
	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT
1. Δ (CB share)	-0.960***	-0.899***	-0.152*	-0.187**	0.190	0.210	-0.048**	-0.039*	-0.030	-0.084
	(0.182)	(0.209)	(0.078)	(0.081)	(0.269)	(0.319)	(0.022)	(0.023)	(0.167)	(0.185)
2. QT1 interaction		0.007		0.531***		-1.110**		-0.297***		0.865***
		(0.670)		(0.194)		(0.548)		(0.087)		(0.323)
3. QT2 interaction		-1.021**		0.286**		0.291		0.009		0.432*
		(0.401)		(0.113)		(0.403)		(0.055)		(0.243)
# of Observations	77	77	77	77	77	77	77	77	77	77
Adjusted R^2	0.397	0.403	0.001	-0.020	0.027	0.040	0.016	0.017	-0.012	-0.017

UK										
	Domestic nonbanks		Foreign nonbanks		Domestic banks		Foreign banks		Foreign official	
	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT
1. Δ (CB share)	-0.723***	-0.720***	-0.090**	-0.105**	-0.079	-0.087	-0.026***	-0.027***	-0.082**	-0.061**
	(0.068)	(0.070)	(0.041)	(0.045)	(0.059)	(0.062)	(0.004)	(0.004)	(0.036)	(0.027)
2. QT interaction		-0.060		0.302		0.159		0.030		-0.433*
		(0.172)		(0.271)		(0.102)		(0.018)		(0.245)
# of Observations	58	58	58	58	58	58	58	58	58	58
Adjusted R^2	0.665	0.659	0.008	-0.001	0.036	0.025	0.055	0.041	0.029	0.050

CA										
	Domestic nonbanks		Foreign nonbanks		Domestic banks		Foreign banks		Foreign official	
	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT
1. Δ (CB share)	-0.736***	-0.738***	-0.060***	-0.063***	-0.064	-0.033	-0.024***	-0.024***	-0.118***	-0.141***
	(0.169)	(0.188)	(0.018)	(0.015)	(0.203)	(0.214)	(0.003)	(0.003)	(0.039)	(0.021)
2. QT interaction		0.032		0.052		-0.419		0.011		0.322***
		(0.323)		(0.180)		(0.381)		(0.028)		(0.071)
# of Observations	77	77	77	77	77	77	77	77	77	77
Adjusted R^2	0.243	0.233	-0.005	-0.018	-0.010	-0.016	0.006	-0.007	0.084	0.115

SW										
	Domestic nonbanks		Foreign nonbanks		Domestic banks		Foreign banks		Foreign official	
	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT
1. Δ (CB share)	0.097	0.436*	-0.840***	-0.902***	-0.273	-0.483	-0.014	-0.198	0.028	0.146
	(0.171)	(0.240)	(0.142)	(0.155)	(0.309)	(0.429)	(0.166)	(0.121)	(0.361)	(0.457)
2. QT interaction		-2.704***		0.498		1.675**		1.468***		-0.939
		(0.323)		(0.387)		(0.667)		(0.194)		(0.792)
# of Observations	46	46	46	46	46	46	46	46	46	46
Adjusted R^2	-0.021	0.049	0.120	0.103	-0.011	0.001	-0.023	0.023	-0.023	-0.037

AU										
	Domestic nonbanks		Foreign nonbanks		Domestic banks		Foreign banks		Foreign official	
	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT
1. Δ (CB share)	-0.612**	-0.567*	-0.089	-0.144	-0.218	-0.230	0.001	0.005	-0.083	-0.065
	(0.304)	(0.325)	(0.176)	(0.186)	(0.164)	(0.174)	(0.029)	(0.029)	(0.060)	(0.063)
2. QT interaction		-1.073***		1.303***		0.282*		-0.092**		-0.418***
		(0.252)		(0.240)		(0.154)		(0.044)		(0.130)
# of Observations	77	77	77	77	77	77	77	77	77	77
Adjusted R^2	0.087	0.086	-0.010	0.002	0.014	0.003	-0.013	-0.024	-0.008	-0.017

NZ										
	Domestic nonbanks		Foreign nonbanks		Domestic banks		Foreign banks		Foreign official	
	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT
1. Δ (CB share)	-0.198***	-0.194***	-0.335***	-0.309***	-0.324***	-0.350***	-0.053***	-0.053***	-0.091*	-0.094*
	(0.048)	(0.052)	(0.054)	(0.052)	(0.093)	(0.101)	(0.013)	(0.015)	(0.049)	(0.051)
2. QT interaction		-0.078		-0.519***		0.525***		0.011		0.063
		(0.106)		(0.132)		(0.180)		(0.042)		(0.083)
# of Observations	77	77	77	77	77	77	77	77	77	77
Adjusted R^2	0.034	0.021	0.163	0.169	0.110	0.112	0.052	0.039	0.047	0.036

Notes: Coefficient estimates from Tables 5.1 and 5.2 based on Equations 5.1 and 5.2. Regressions also include a constant term which was not significant and is dropped from the tables for ease of presentation. Standard errors reported in parentheses. Asterisks represent coefficients that are significant at the 1% (***), 5% (**), and 10% (*) levels.

Pooled panel regressions										
	Domestic nonbanks		Foreign nonbanks		Domestic banks		Foreign banks		Foreign official	
	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT
1. Δ (CB share)	-0.790***	-0.743***	-0.136***	-0.161***	0.025	0.022	-0.035**	-0.032***	-0.064**	-0.086***
	(0.106)	(0.093)	(0.022)	(0.025)	(0.103)	(0.110)	(0.009)	(0.007)	(0.022)	(0.006)
2. QT interaction		-0.670***		0.351**		0.048		-0.044		0.313
		(0.121)		(0.101)		(0.113)		(0.038)		(0.211)
# of Observations	462	462	462	462	462	462	462	462	462	462
R^2	0.298	0.308	0.015	0.020	0.001	0.001	0.016	0.017	0.009	0.015

Notes: Coefficient estimates from Tables 5.1 and 5.2. Panel regressions weight each economy by relative GDP in USD terms, include country fixed effects, and cluster robust standard errors at the country level. Standard errors reported in parentheses. Asterisks represent coefficients that are significant at the 1% (***), 5% (**), and 10% (*) levels.

Appendix Table A5.2
Regression Results with Individual Country Data with and without QT Dummies

US

	Households		Broker & dealers		Pension		Insurance		Investment funds		State and Local		Others	
	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT
1. Δ (CB share)	-0.506***	-0.450***	-0.095**	-0.095**	-0.188*	-0.156	0.004	0.006	-0.059	-0.085	0.066	0.077	-0.004	0.008
	(0.064)	(0.080)	(0.042)	(0.048)	(0.113)	(0.125)	(0.006)	(0.007)	(0.065)	(0.076)	(0.044)	(0.050)	(0.015)	(0.014)
2. QT1 interaction		-0.434		0.012		-0.410		0.050*		0.255**		0.039		-0.157***
		(0.298)		(0.120)		(0.289)		(0.027)		(0.116)		(0.163)		(0.042)
3. QT2 interaction		-0.693***		-0.006		-0.314		-0.059***		0.306***		-0.202*		-0.103***
		(0.255)		(0.077)		(0.242)		(0.020)		(0.104)		(0.121)		(0.036)
# of Observations	77	77	77	77	77	77	77	77	77	77	77	77	77	77
Adjusted R^2	0.256	0.263	0.040	0.014	0.056	0.047	-0.011	-0.005	0.036	0.094	0.022	0.014	-0.013	-0.004

UK

	Households		Insurance		Investment funds		State and Local		Others	
	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT
1. Δ (CB share)	0.004	0.004	-0.215***	-0.208***	-0.449***	-0.430***	0.000	0.000	0.001	0.001
	(0.002)	(0.002)	(0.045)	(0.043)	(0.069)	(0.071)	(0.000)	(0.000)	(0.001)	(0.001)
2. QT interaction		-0.009**		-0.365***		-0.999***		0.002**		-0.001
		(0.004)		(0.119)		(0.343)		(0.001)		(0.001)
# of Observations	57	57	57	57	57	57	57	57	57	57
Adjusted R^2	0.049	0.038	0.253	0.251	0.382	0.400	-0.018	-0.035	-0.006	-0.025

CA

	Households		Broker & dealers		Insurance		Investment funds		State and Local		Others	
	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT
1. Δ (CB share)	-0.068***	-0.071***	-0.065***	-0.068***	-0.459***	-0.482***	0.110***	0.132***	-0.056	-0.041	-0.133***	-0.155***
	(0.015)	(0.018)	(0.019)	(0.020)	(0.123)	(0.124)	(0.035)	(0.028)	(0.036)	(0.044)	(0.044)	(0.042)
2. QT interaction		0.046		0.044		0.311*		-0.291		-0.193***		0.297
		(0.054)		(0.052)		(0.164)		(0.261)		(0.067)		(0.194)
# of Observations	77	77	77	77	77	77	77	77	77	77	77	77
Adjusted R^2	0.013	0.000	0.028	0.017	0.263	0.261	-0.001	-0.009	-0.002	-0.007	0.009	0.002

AU

	Households		Pension		Insurance		Investment funds		Others	
	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT	W/O QT	W/ QT
1. Δ (CB share)	0.000	0.000	-0.079**	-0.078**	-0.207*	-0.207*	-0.189**	-0.190**	-0.023	-0.022
	(0.000)	(0.000)	(0.037)	(0.037)	(0.118)	(0.118)	(0.075)	(0.075)	(0.016)	(0.016)
2. QT interaction		-0.004***		-0.177*		-0.176		0.088		-0.214***
		(0.001)		(0.094)		(0.175)		(0.217)		(0.057)
# of Observations	77	77	77	77	77	77	77	77	77	77
Adjusted R^2	-0.006	-0.015	0.059	0.047	0.081	0.068	0.099	0.087	0.024	0.020

Notes: Coefficient estimates from Tables 5.3 and 5.4 based on Equations 5.1 and 5.2. Regressions use country specific data sources as described in the text. Standard errors are reported in parentheses. Asterisks represent coefficients that are significant at the 1% (***), 5% (**), and 10% (*) levels.