Staff memo

The macroeconomic effects of Riksbank asset purchases during the pandemic: simulations using a DSGE model

Yıldız Akkaya, Carl-Johan Belfrage, Paola Di Casola and Ingvar Strid

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Table of contents

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Summary

In response to the economic downturn caused by the coronavirus pandemic the Riksbank implemented measures to prevent liquidity shortages from affecting credit supply and ensure low interest rates for households and firms. The measures consisted mainly of providing liquidity support and purchasing assets. During 2020-2021 the Riksbank's holdings of government, municipal and covered bonds increased by SEK 560 billion, which is roughly 10 percent of GDP in 2021. In this Staff memo we use a macroeconomic model to simulate the effects of these pandemic-induced bond purchases on the Swedish economy. The purchases lowered interest rates, depreciated the Krona exchange rate and increased demand. An overall assessment based on our approach suggests that the purchases increased GDP by 0.2 percent and inflation by 0.25 percentage points on average in 2020-2023. The purchases of municipal and covered bonds account for roughly half of these effects, while the purchases of government bonds account for the other half. However, our approach provides a low estimate of the effects as it does not capture that the Riksbank's asset purchases reduced the likelihood of a financial crisis.

Authors: Yıldız Akkaya, Carl-Johan Belfrage, Paola Di Casola and Ingvar Strid.[1]

[1] Carl-Johan Belfrage and Ingvar Strid work in the Riksbank's monetary policy department. Yıldız Akkaya and Paola Di Casola work at the European Central Bank. Part of the work was conducted when they were affiliated with the Riksbank. We would like to thank Mikael Apel, Vesna Corbo, Mattias Erlandsson, Peter Gustafsson, Jesper Hansson, Jens Iversen, David Vestin, Anders Vredin and seminar participants at the Riksbank for helpful comments and discussions.

1 Introduction

During and following the global financial crisis in 2007-2009 and the subsequent sovereign debt crisis in Europe, a number of central banks decreased policy rates to their effective lower bounds and initiated large-scale purchases of financial assets. The types of assets purchased include government bonds, corporate bonds, covered bonds issued by banks and even equities. In Sweden, the Riksbank lowered the policy rate below zero and started to purchase government bonds in February 2015.

The main goal of central bank asset purchases, often referred to as quantitative easing (QE), is to lower interest rates and ease financial conditions in order to support aggregate economic activity and increase inflation towards the central bank's target. By the end of the 2010s it appeared that these objectives had been broadly attained in many of the countries whose central banks engaged in QE and the monetary policy discussion concerned the coming reduction of central bank asset holdings.[2] However, in response to the coronavirus pandemic and the sharp fall in economic activity in 2020, central banks lowered policy rates and resumed and substantially increased asset purchases to support the functioning of financial markets and stimulate the economy. In Sweden, the Riksbank assessed that it would not be effective to lower the policy rate from its prevailing level at zero and decided on asset purchases amounting to in total SEK 700 billion.[3,4]

In related work we have used a small open economy two-region dynamic stochastic general equilibrium (DSGE) model with segmented asset markets to assess the effects of foreign and domestic central bank purchases of government bonds on the Swedish economy after the global financial crisis in 2007-2009 and during the coronavirus pandemic in 2020-2021, see Akkaya et al. (2023).[5] In this model, central bank bond purchases induce households to rebalance their asset portfolios, leading to lower term

[2] Brainard (2017), Constancio (2017) and Flodén (2018) are examples of contributions to this discussion from individual governors of the Federal Reserve, the ECB and the Riksbank.

[3] On the decision not to lower the policy rate further, see Sveriges Riksbank (2020), p.12.

[4] A detailed account of how the pandemic affected financial markets in 2020 and how the Riksbank responded to the pandemic is provided by Gustafsson and von Brömsen (2021). The asset purchases were announced as an envelope for total purchases over a longer period of time. The first announcement was made on 16 March 2020 where it was decided that the Riksbank would buy assets for a maximum of SEK 300 billion. At each of the announcements on 1 July and 26 November 2020 the envelope was expanded by a further SEK 200 billion. The Riksbank decided to buy mainly government, municipal and covered bonds but also a small amount of corporate bonds (SEK 12 billon). Aside from the bond purchases, included in the envelope for asset purchases were also holdings of treasury bills (up to SEK 20 billion) and commercial paper (up to SEK 32 billion). The Riksbank's measures also included loans to banks for onward lending to firms, lowered interest rate in the lending facility, weekly market operations at longer maturities in kronor, eased collateral requirements when borrowing from the Riksbank and loans to banks in US dollars. Overall, the Riksbank's asset purchases related to the coronavirus pandemic amounted to somewhat less than 15 percent of annualized 2019Q4 GDP while the asset purchases by the Federal Reserve, the European Central Bank and the Bank of England each amounted to roughly 20 percent of annualized 2019Q4 GDP, see Lane (2022).

[5] Effects of Riksbank bond purchases on GDP in the period 2015-2021 obtained using this model have also been reported by Kjellberg and Åhl (2022). Their reported effects are in line with the effects in Akkaya et al et al. (2023) and this staff memo.

premia and long-term bond rates and a depreciation of the currency.[6] In this staff memo we apply the model to study the effects of the Riksbank's bond purchases during the pandemic, with a particular focus on the purchases of municipal and covered bonds.[7] However, since the model is not designed to study central bank purchases of private assets we need to make additional assumptions to compute the effects.

Our approach consists of three parts. First, we re-calibrate the model to account for the extended set of debt instruments, now including municipal and covered debt as well as government bonds. Second, we attempt to roughly match the effects of the Riksbank's purchases on bond yields to the evidence from the event study of Gustafsson (2022). Third, we make additional assumptions to be able to attribute effects on bond yields and other macroeconomic variables to the purchases of the different types of bonds.

We contrast the estimates obtained using this approach to those obtained with an alternative approach where it is instead assumed that purchases of government, municipal and covered bonds have the same effects on macroeconomic variables.

We compute the effects of pandemic-related government, municipal and covered bond purchases separately.[8] The combined purchases increased GDP by roughly 0.2 percent and inflation by 0.25 percentage points on average in 2020–2023, i.e. during the period when the purchases occurred or had their largest macroeconomic effects. We attribute roughly half of these effects to the purchases of government bonds while the other half is attributed to the purchases of municipal and covered bonds. If it is instead assumed that municipal and covered bond purchases have the same effects as government bond purchases the corresponding estimates are 0.3 percent for GDP and 0.4 percentage points for inflation.[9] Our estimates are obviously uncertain, for a variety of reasons, some of which are discussed further below.[10] Most importantly, in the initial stage of the pandemic there was a risk that the situation would develop into a financial crisis. The measures taken by the Riksbank and other central banks, including asset purchases, reduced the likelihood of such an event. Since we cannot fully capture such effects using our approach it is likely that we underestimate

[6] The effects of QE are often described schematically through different channels, see e.g. Melander (2021). In the model used here QE works through term premium, portfolio rebalancing and exchange rate channels. When we simulate effects of QE we also allow for the possibility that the central bank keeps the policy rate constant, which may be interpreted as a signalling channel of asset purchases.

[7] We do not consider the effects of Riksbank purchases of treasury bills, corporate bonds and commercial paper. The main reason for this is that in the model we use they would have no or minimal macroeconomic effects on account of their short duration and small size.

[8] The effects of government bond purchases are obtained in the same way as, and therefore identical to, those reported in Akkaya et al. (2023).

[9] To put the inflation effects into perspective one may ask how much the policy rate would need to be lowered to obtain the equivalent effect. Using the inflation response to an unanticipated monetary policy shock in the macroeconomic model MAJA for Sweden we find that the policy rate would need to be 0.9 (1.2) percentage points lower on average in 2020-2023 to increase inflation by 0.25 (0.35) percentage points on average. For a description of the model see Corbo and Strid (2020).

[10] We briefly discuss the uncertainty of our estimates in the appendix. We choose not to report intervals to illustrate the uncertainty since it is difficult to attach probabilities to the different approaches and assumptions considered in the memo. However, the underlying simulations are reported in the appendix which makes it possible to understand how different assumptions affect the results.

the positive effects of the pandemic-related asset purchases on economic activity and inflation.[11]

This staff memo is organised in the following way. In section 2 we provide a brief description of the model and discuss conceptual and calibration issues which arise when the measure of debt is extended to include municipal and covered bonds. Next we illustrate how the model can be applied to compute the effects of asset purchases by revisiting the case of the Riksbank's government bond purchases during the pandemic, which was also studied by Akkaya et al. (2023). In section 3 we discuss the additional assumptions needed to compute the effects of municipal and covered bond purchases and present simulation results. Section 4 concludes the memo.

[11] Bailey et al. (2020) observe that decisive QE programmes may be particularly effective in times of market dysfunction and that a rapid pace of asset purchases may enhance their effectiveness. These are forms of state contingent effects of QE. For example, Lane (2022) mentions that the ECB PEPP's removal of the financial tail risk associated with the pandemic is estimated to have had an additional and much larger effect on economic activity than in a situation with calm financial markets.

2 Effects of the Riksbank's purchases of government bonds during the pandemic

2.1 The model

Our tool for computing the effects of central bank asset purchases is a calibrated small open economy DSGE model with segmented asset markets, based on work by Kolasa and Wesolowski (2020). In a companion paper we calibrate the model using Swedish data and compute the effects of foreign and domestic central bank government bond purchases in the period from the global financial crisis in 2007–2009 to the end of 2021, see Akkaya et al. (2023). Here we provide a very brief description of the model (with the reader being referred to the two papers referenced above for a more comprehensive presentation) and discuss how the model can be applied to study also the purchases of municipal and covered bonds.

The model consists of two countries, a small country (home) and a large country (foreign) each inhabited by households, firms and a government. There are four assets available for saving: domestic and foreign short- and long-term government bonds. There are costs of holding long-term debt, which give rise to term premia that may differ between countries. Central banks may affect those term premia by purchasing long-term debt (sometimes simply referred to as bonds below). When a central bank purchases bonds it reduces the effective supply of bonds to investors and therefore induce them to rebalance their bond portfolios (to short-term domestic debt or long-term foreign debt), while bond prices increase (i.e. bond yields fall). The decrease in the bond yields raises demand and inflation as saving becomes a less attractive option and at the same time a currency depreciation follows. The exchange rate channel is important for the effects of QE (both foreign and domestic) on the small economy.[12]

Our purpose is to use the model to study the effects of the Riksbank's purchases of government, municipal and covered bonds on Sweden. This raises both conceptual and calibration-related issues since it requires us to consider a larger set of debt instruments than was originally considered in the construction of the model.

The main question is whether municipal and covered bonds are sufficiently similar to government bonds in the eyes of investors to be included in the same framework. By including municipal debt we would just be broadening the definition of government debt from central to general (i.e. also including local) government debt. The default

[12] The exchange rate effects are guided by a long-term UIP condition which states that expected one-period rates of return on home and foreign long-term debt are the same when expressed in the same currency. Since it is assumed that households cannot trade short-term debt issued abroad, the expected returns on home and foreign short-term debt expressed in the same currency need not be equal. In Akkaya et al. (2023) we provide a more detailed description of how foreign and domestic QE affects the two economies in the model. The effects of central bank asset purchases are often described through various channels. Our model captures the term premium, portfolio rebalancing and exchange rate channels of QE. When simulating the effects of QE we also allow for the possibility that agents anticipate the policy rate to be kept constant at a low level. This may be interpreted as a signalling channel of QE.

risk on Swedish municipal bonds is generally low for two reasons. First, municipalities can adjust local income taxes when needed, thus backing their creditworthiness by power of taxation in a way similar to the central government. Second, a large part of municipal bonds (and in particular those purchased by the Riksbank) are jointly guaranteed by a large number of Swedish municipalities and regions.[13] Covered bonds, on their part, are issued by banks mostly to finance residential mortgages. They are widely considered to feature low risk as they are backed by cover pools of mortgages to which investors have a preferential claim in the event of default and because they are usually issued by systemically important and strongly regulated banks.[14]

We draw the conclusion that municipal and covered bonds are indeed sufficiently similar to government bonds to warrant applying the model as an imperfect tool to compute the effects of municipal and covered bond purchases.[15] In order to lend credibility to this exercise we re-calibrate the model to account for the larger set of debt instruments, and consider different assumptions on how strongly the purchases of different types of bonds affect interest rates in the economy. These assumptions are discussed in more detail in section 3.1.

2.2 Calibration

The model is calibrated so that the United States, the euro area and the United Kingdom together constitute the large economy while the small economy is represented by Sweden.[16] As detailed in Akkaya et al. (2023), the model parameters can be broadly divided into those that are common to many New Keynesian DSGE models (standard parameters) and those that in various ways relate to debt and therefore are more specific to this model (debt parameters). The large economy parameters are either calibrated as in Kolasa and Wesolowski (2020) or broadly in line with them. For Sweden, the calibration of the standard parameters is largely based on the estimated parameter values in MAJA, a two-country DSGE model for Sweden (Corbo and Strid, 2020). The main difference between the calibrations of standard parameters in Kolasa and Wesolowski (2020) and Akkaya et al. (2023) concern the slope parameters in the

[13] These are the bonds issued by Kommuninvest, a credit institution owned collectively by a large number of Sweden's municipalities and regions. We note, however, that municipal bonds are less liquid than treasury bonds, hence feature a somewhat higher interest rate.

[14] There are no known defaults on covered bonds and in the cases where their issuers have failed, their covered bond programmes have been unaffected, in many cases due to government or other public sector intervention, see Kemmish et al. (2017). The preferential claim of investors on the cover pool of mortgages in case of default is a key difference from a similar, but more risky type of asset, i.e. asset-backed securities.

[15] An alternative approach would be to focus on the default risk component by using models that feature a banking sector with financial frictions and are designed for analysing central bank purchases of corporate bonds, such as Gertler and Karadi (2013), Sims and Wu (2021) and Boehl et al. (2022).

[16] We follow Kolasa and Wesolowski (2020) in choosing these three countries/regions to represent the large economy. Their central banks implemented QE and, furthermore, they are important trading partners of Sweden.

Phillips curves. In the latter paper the values of those parameters have been decreased in order to provide responses to conventional monetary policy shocks which are more in line with other estimates for Sweden.[17]

The calibration of the debt parameters for Sweden are discussed in detail in Akkaya et al. (2023). The guiding principle was, as far as possible, to select parameter values that are in line with the data since the early 2000s, and in particular the period after the global financial crisis in 2007−2009 and before the start of QE in Sweden in 2015. The calibration of these parameters first requires that the measures of long- and short-term debt are defined. In the government bond calibration long-term debt consists of nominal, inflation-linked and green government bonds issued in Swedish krona. The cut-off between what is treated as long-term and short-term debt, respectively, is a time to maturity of one year. Furthermore, we consider only debt issued in domestic currency primarily because foreign currency-denominated debt instruments have not been purchased by the Riksbank and would not fit the analytical framework. The steady state duration of long-term bonds in the model is calibrated to 6 years.

An important aspect of the calibration is to target effects of asset purchases on term premia or long-term interest rates in line with the evidence from previous studies. The Riksbank's pre-pandemic purchases of government bonds amounted to roughly 10 percent of GDP and in the simulations by Akkaya et al. (2023) they lowered the term premium on the long-term government bond by roughly 50 basis points. This effect is in line with the evidence from a large number of studies both for Sweden and other countries.[18]

When the model is used to shed light on the effects of purchases of municipal and covered bonds, in one of our approaches a subset of the model parameters is re-calibrated. Extending the debt measure to include municipal and covered bonds naturally implies that the debt to GDP ratio is increased, both in the large and small economies. We also re-calibrate the duration of bonds to reflect the shorter average duration of municipal and covered bonds.[19] Finally, we target effects of the Riksbank's pandemic bond purchases on bond yields in line with the evidence in Gustafsson (2022). This is discussed further in section 3.1 and in more detail in the appendix. The re-calibrated parameters are collected in table A1 in the appendix.

[17] This is discussed in more detail in Akkaya et al. (2023). The peak response of inflation to a monetary policy shock with the values for the Calvo parameters used by Kolasa and Wesolowski (2020) is roughly twice as large as the corresponding effect in MAJA. The inflation response in MAJA is also broadly in line with responses in structural VAR models estimated on Swedish data for the inflation targeting period.

[18] See the references in Akkaya et al. (2023), section 4. An important parameter when matching the effects of bond purchases on term premia and long-term bond yields is a transaction cost parameter which governs the elasticity of the term premium with respect to bond purchases.

[19] We have used data from the Swedish National Debt Office (SNDO) on the duration of the outstanding stock of nominal and real krona debt, as well as on the duration of the Riksbank's holdings of government bonds (of which the latter is intended to be roughly in line with the former) in recent years to arrive at the calibration of the duration of long-term government debt to 24 quarters. For municipal and covered bonds, we have relied on data on the duration of the Riksbank's holdings as well as Swedish Bankers' Association data on the time to maturity of the outstanding stock of covered bonds, to arrive at a calibration of the duration of those bonds. The calibration of the duration to 16 quarters is a weighted average of government, municipal and covered bond duration assessments.

2.3 Riksbank government bond holdings and simulation methods

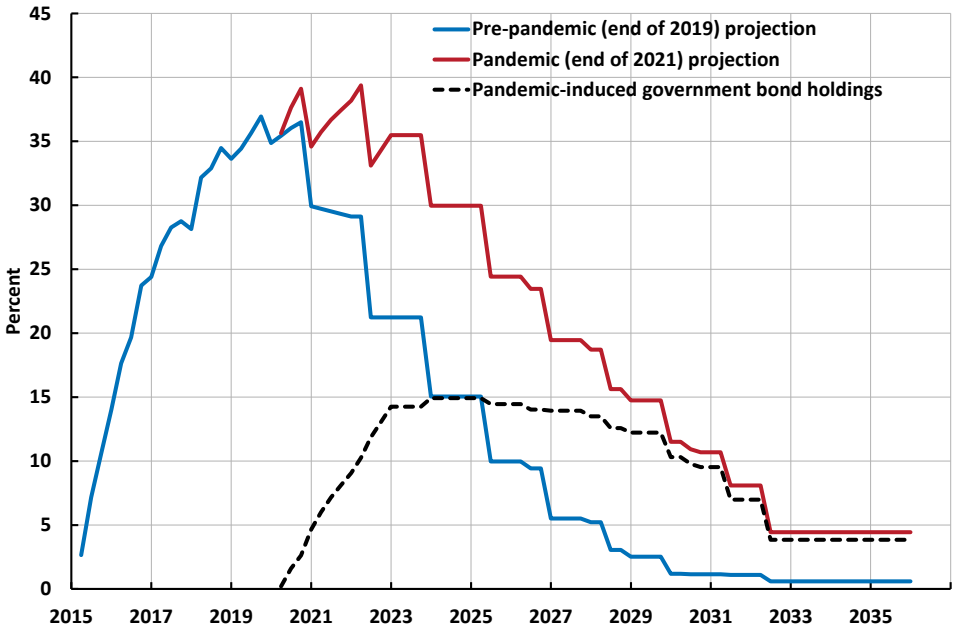
In Akkaya et al. (2023) we use the model to compute the macroeconomic effects of Riksbank government bond purchases before and during the pandemic. Here we lay out how the effects of pandemic-induced government bond purchases are obtained in the abovementioned paper and reproduce these effects. This allows us to discuss the measure of QE and the assumptions on agents' expectations about bond purchases and the policy rate in our simulations. Later we employ similar assumptions when computing the effects of municipal and covered bond purchases.

In the model the variable that describes quantitative easing is the value of long-term government debt purchased by the central bank as a share of total government debt. We refer to this variable as QE, and its time series as the QE path. In figure 1 we show the QE path that represents the Riksbank's holdings of government bonds that resulted from the purchases made in response to the coronavirus pandemic, see the black dashed line. This path is constructed as the difference between two paths: i) the projection of the Riksbank's holdings of government debt prior to the pandemic (blue line) and (ii) the outcome for 2020-2021 and a projection for 2022 and onwards based on information at the end of 2021 (red line). The difference thus captures how the pandemic altered the outlook for the Riksbank's government bond holdings, i.e. it captures the surprise component of bond holdings associated with the pandemic.[20, 21]

[20] The pre-pandemic QE path for Sweden is based on the forecast for the Riksbank's holdings of government bonds in 2020, and the technical projection for bond holdings in 2021-2028, presented in the Monetary Policy Report in December 2019. The technical projection assumed that no further asset purchases were to be made but that all bonds would be held to maturity implying a gradual reduction in the Riksbank's bond holdings. For the projection of pre-pandemic bond holdings beyond 2028 we have assumed that the rather small (2.7 billion) difference between the projected holdings at the end of 2028 and the bonds already held at the end of 2019 yet maturing after 2028, was equally distributed between bonds maturing after 2028 that were in the Riksbank's portfolio at the end of 2020. The construction of the pandemic QE path for Sweden draws on the Riksbank's communication in the Monetary Policy Report in November 2021, where it was stated that total bond holdings would remain roughly unchanged during 2022 and gradually decline thereafter. The simultaneously published decision on the distribution of purchases between government, municipal and covered bonds in the first quarter of 2022 involved an equal distribution of purchases between those bond types, implying that the holdings of government and covered bonds would start declining while the holdings of municipal bonds would increase during the year. The gradual decline of the Riksbank's bond holdings beyond 2022 has been assumed to be the result of no further asset purchases taking place and all bonds being held to maturity.

[21] Following the rapid increase in inflation in 2022, the Riksbank's plan for bond purchases has been somewhat revised in favour of smaller purchases during the second half of the year, implying measures for the Riksbank's holdings of government bonds that are 1.5 percentage points lower at the end of 2022 than what is shown in the figure and has been used for our simulations. Since the QE adjustments in response to the high inflation in 2022 were not anticipated during 2020-2021, accounting for them in our framework would require an additional QE path and separate simulations like we have done for the difference between the pre-pandemic and pandemic projections. We have chosen not to do so since the difference is small enough not to matter for our conclusions about the macroeconomic effects of Swedish QE and since our primary interest is in the effects of the monetary policy response to the pandemic.

Figure 1. The Riksbank's holdings of government bonds as a share of the outstanding stock of SEK-denominated central government debt[22]



Note: The pre-pandemic projection is based on outcomes for bond holdings during 2015Q1-2019Q4 and a projection for 2020Q1 and onwards. The pandemic projection is based on outcomes for bond holdings during 2015Q1-2021Q4 and a projection for 2022Q1 and onwards. The pandemic-induced government bond holdings are the result of purchases induced by the pandemic, i.e. the difference between the pandemic and pre-pandemic projections.

We simulate the effects of pandemic-related government bond purchases using different assumptions on agents' expectations about QE and the response of the central bank policy rate in order to cover various possible alternatives.[23] First, we consider the cases where QE is fully, or only partly, anticipated. In the former case it is assumed that the whole path of asset purchases becomes known to the agents when

[22] In addition to the projections for bond holdings, the construction of the QE paths also rely on projections for the denominator in the QE measure, i.e. total government debt. When calculating the effects of pre-pandemic QE we have used a forecast for total government debt as it could reasonably have been constructed at the end of 2019, using SNDO forecasts for net borrowing in 2020-2021 and the assumption of a constant nominal debt level thereafter. The large fiscal response to the pandemic meant more borrowing and a different path for government debt beginning in 2020. We have chosen not to let this change in fiscal policy influence our calculations of pandemic QE by using the just described forecast for total government debt also when calculating the pandemic QE path. The difference between the red and blue paths in the figure are hence only due to the differences in the projections for the Riksbank's bond holdings.

[23] Note that we do not study the effects of pandemic-induced changes in policy rate expectations per se. Lowering the policy rate would be a complement to asset purchases in order to stimulate the economy and not a response to the effects of bond purchases. The Riksbank's policy rate projections for 2020 were not changed between February and April 2020, in both cases the forecast was flat at zero. The policy rate expectations of money market players in the Prospera survey decreased somewhat in the spring of 2020, e.g. the expectations 3 and 12 months ahead decreased by around 0.15 percentage points from the beginning of March to the end of April.

the purchase program is launched. In the latter case, at each point in time, agents instead assume that central bank bond holdings will stay (approximately) unchanged.[24] We label these cases 'anticipated' and 'unanticipated', respectively. Second, we consider the case where the central bank policy rate responds to the expansionary effects of QE as well as the case where the policy rate is kept constant. Central bank asset purchases have typically been introduced when the scope for decreasing the policy rate further has been limited and have often been coincident with forward guidance (FG) on the policy rate. In such situations, asset purchases may be interpreted by agents as a signal that the policy rate will be held low for longer.[25] This suggests that the constant rate assumption is more relevant in order to capture the overall effects of monetary policy when the policy rate is close to an effective lower bound. On the other hand, it is well-known that DSGE models suffer from the so-called 'forward guidance puzzle', which implies that the effects of holding the interest rate constant are presumably exaggerated. In order to avoid unreasonably large effects we assume that the central bank is anticipated to keep the policy rate fixed at the lower bound for four periods following the start of QE.[26]

The main differences between the simulation methods in terms of effects on the economy are the following. First, the constant rate assumption implies that the positive effects of bond purchases on the economy are larger.[27] Second, if the QE path is anticipated by agents the effects on the economy are more immediate. In our simulations the assumption on expectations – anticipated or unanticipated bond purchases – mainly affects the timing of the effects while the peak effects are generally of similar size.

In total we then have four variants for simulation of the effects of QE which span a spectrum of possible cases. Since it is not obvious which set of assumptions should be

[24] This is achieved by assuming an exogenous process for the QE path which is very persistent, a near unit root. Since bond holdings are assumed to stay roughly unchanged (a near random walk forecast) net purchases of bonds, i.e. changes in holdings, are assumed to be completely unanticipated.

[25] This is the signalling channel of central bank asset purchases. If the central bank has a large holding of bonds and increases the policy rate, its financial result will be affected negatively. If agents believe that the central bank wants to avoid losses they will expect the policy rate to be held low for a longer period. Bond purchases thus increase the credibility that the policy rate will be kept low. Bhattarai et al. (2022) offer a formal exposition of this argument. Several studies suggest that the signalling channel may have been important. For instance, in an event study of the Federal Reserve's QE1 and QE2 programs, Krishnamurty and Vissing-Jorgensen (2011) find an important role for the signalling channel in lowering bond yields.

[26] Se e.g. McKay et al. (2016) on the forward guidance puzzle. Central banks, including the Riksbank, have kept the policy rate constant at low levels for longer periods than 4 quarters. But assuming that the policy rate is anticipated by agents to be fixed at a low level for a long period in a DSGE model generates unrealistically large effects on macroeconomic variables. It is beyond the scope of this paper to discuss the consequences of the forward guidance puzzle in detail. We note that both Kolasa and Wesolowski (2020) and Chen et al (2012) employ a similar assumption on the length of the constant interest rate period.

[27] During the 15-month period leading up to the introduction of pandemic QE in Sweden, the Riksbank had raised its policy rate from -0.5 percent to 0 percent and kept it there until May 2022. This argues against treating the policy rate as being at its lower bound when the decisions on QE purchases were made. On the other hand, it was possible to interpret the Riksbank's rate hikes to the zero level (the hike from -0.25 to 0 percent in December 2019 was undertaken against a backdrop of inflation outcomes near its historical low and rising unemployment) as well as some of its communication (e.g. the press release announcing the December 2019 monetary policy decision indicating that should economic developments turn out to be worse than forecast, other measures would be considered alongside policy rate cuts) as indications of an aversion to negative policy rates going forward.

preferred, we choose to average the effects of the four simulations. To simplify the exposition we only present the average effect in the main text and the individual simulations are reported in the appendix.

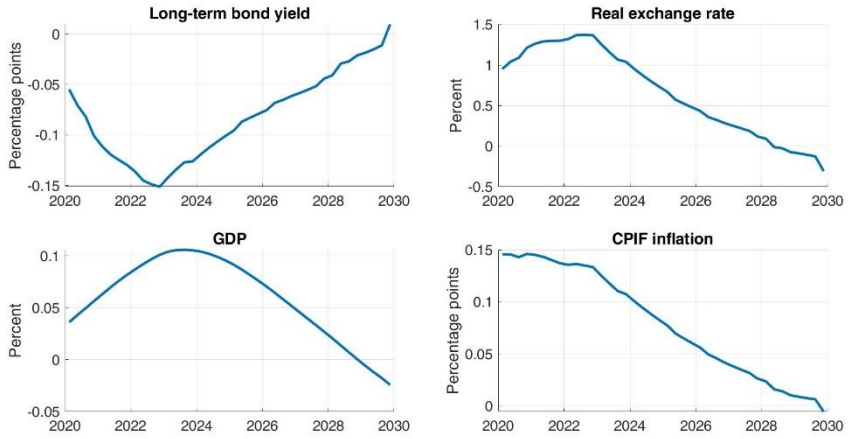
2.4 Effects of the Riksbank's government bond purchases during the pandemic

The effects of the Riksbank's government bond purchases during the pandemic on key macroeconomic variables are shown in figure 2. These effects are identical to those presented in Akkaya et al. (2023). We note again that these effects are obtained with the calibration of the model in that paper, which means that the effect of a given amount of government bond purchases is assumed to be the same during and before pandemic. The purchases induce a decrease in the term premium and the long-term government bond rate. The effect on the long-term bond yield is 5−15 basis points in 2020-2023. In Gustafsson (2022) the total effects of the Riksbank's asset purchases in 2020 on 2, 5 and 10 year government bonds are estimated to be −10, −15 and −19 basis points.[28] The pandemic-induced purchases of government, municipal and covered bonds were announced simultaneously in 2020, hence it is difficult to distinguish their effects on government bond yields. However, combining our estimates of the effects of government bond purchases on bond yields with the evidence from Gustafsson (2022) would suggest that roughly half of the effects on government bond yields were due to the purchases of government bonds.

With Swedish long-term rates decreasing and foreign long-term rates being unaffected, saving in domestic bonds becomes a less attractive alternative relative to foreign bonds. Therefore capital flows out of Sweden and the Krona exchange rate depreciates. Increased demand for exports leads to an increase in GDP. Increased aggregate demand and higher prices of imported goods lead to an increase in inflation. The real exchange rate depreciates by roughly 1 percent in 2020-2023, GDP increases by 0.05−0.1 percent and inflation increases by 0.1−0.15 percentage points. We also note that the effects of purchases last a long time after the pandemic period. This mainly reflects the fact that the pandemic persistently altered the outlook for the Riksbank's government bond holdings, i.e. the pandemic-induced QE path (black dashed line) in figure 1 decreases slowly.

[28] These are the total effects, i.e. the sum of measured and extrapolated effects, of the Riksbank's announcements of asset purchases on 16 March, 1 July and 26 November, reported in Table 4 in Gustafsson (2022). We consider the government bond yield spreads relative to German yields.

Figure 2. Effects of the Riksbank's government bond purchases during the pandemic



Note: The real exchange rate and GDP are in levels and CPIF inflation is in annualised quarterly change. The average effects from 4 simulations are shown. These effects are also reported in Akkaya et al. (2023). The individual simulations are shown in the appendix of the same paper.

3 Effects of the Riksbank's purchases of municipal and covered bonds

3.1 Method

Above we have discussed how Akkaya et al. (2023) use a DSGE model to compute the effects of the Riksbank's government bond purchases made in response to the pandemic. In this section, our main objective is to compute the effects of the purchases of municipal and covered bonds which were also a part of the Riksbank's response to the pandemic. We retain the model and the framework in that paper for the computation of the effects. The model was not designed to study central bank purchases of private bonds, hence we need to invoke additional assumptions and use a re-calibrated version of the model.

We consider two approaches, which are denoted A1 and A2. In our main approach, A1, we match the effects of the Riksbank's pandemic-induced bond purchases on bond yields in the model to the evidence from event studies. In our second approach, A2, we assume that a given amount of the Riksbank's purchases of municipal and covered bonds have the same effects on the economy as purchases of government bonds.

In approach A1 we compute the effects of the purchases of government, municipal and covered bonds separately to allow for the possibility that they may have different effects on the economy. This approach could be motivated by the observation that

the effects on asset prices depend on which assets are purchased, see e.g. Krishnamurthy and Vissing-Jorgensen (2011).[29] It follows that the composition of the bond purchase programme should matter for the effects on the interest rates that households and firms encounter, and therefore also for the effects on macroeconomic variables.

For each type of bond we aim to match the effect of the purchases on yields according to an event study conducted by Gustafsson (2022). Combining these event-study estimates of the effects of the purchases on government bond yields with our simulated effects (which were discussed in section 2), we infer that the government bond purchases accounted for roughly half of the effects on government bond yields. Consequently, we assume that the purchases of municipal and covered bonds accounted for the other half of the decline. Next we invoke additional assumptions to be able to similarly attribute the decline in the municipal and covered bond yields to purchases of the different types of bonds. Our main assumptions are:

- Purchases of government bonds have broad effects, they reduce the yields of government, municipal and covered bond yields in the same way.
- The covered (municipal) bond risk premium is only affected by purchases of covered (municipal) bonds.

With these assumptions we can decompose the total effects of the bond purchases on yields into contributions from purchases of the different types of bonds. We then compute the effect of purchases of the different bonds on the *average bond yield*, which is defined as a weighted average of the government, municipal and covered bond yields. This yield is intended to be a proxy for the interest rates which households and firms face. Finally, the DSGE model is calibrated such that the simulated effects of bond purchases on bond yields in the model are in line with the empirical effects obtained using the approach outlined above, summarised by the effect on the average bond yield. A detailed description of the approach, including motivations of the assumptions presented above, is provided in the appendix.

Our second approach, A2, can be considered a simple benchmark. Here we assume that the effects of the purchases of municipal and covered bonds are equal to the effects which would have been obtained if the Riksbank had instead purchased government bonds. Specifically, in this approach we assume that a particular path for the nominal value of the Riksbank's bond holdings will have the same effects regardless of whether those bond holdings consist of municipal, covered or government bonds.[30]

[29] While our argument for using the model to compute the effects of covered and municipal as well as government bonds rested on these bond types being viewed as similar by investors, the "local supply effect" used here to motivate why the composition of purchases may matter implies that the different types of bonds are not treated as perfect substitutes. This combination is quite possible as long as there is a demand for variety in the portfolios of individual investors or if the preferred bond type varies among investors.

[30] Since municipal and covered bonds typically have a shorter time to maturity, a given path for bond holdings involves more frequent purchases of those types of bonds than government bonds.

We then apply the approach and model calibration of Akkaya et al. (2023), which was described in section 2, to compute the effects.[31]

3.2 Results

The QE paths for municipal and covered bonds are shown in figure 3. These paths are based on the Riksbank's purchases in 2020–2021 and a projection of the holdings from 2022 and onwards made at the end of 2021. At that time the Riksbank held SEK 105 billion of municipal bonds and SEK 405 billion of covered bonds. That corresponded to 3 and 15 percent, respectively, of the sum of the outstanding stocks of central government debt and interest-bearing debt of issuers of municipal and covered bonds.[32] As already noted in section 2.3, the construction of the paths for the Riksbank's bond holdings draws on the Riksbank's communication in the Monetary Policy Report in November 2021 and the simultaneously communicated decisions on the distribution of bond purchases in the first quarter of 2022, which together pointed to likely paths for the Riksbank's holdings of municipal bonds (increasing) and covered bonds (declining) during 2022.[33] The communication of a gradual decline of bond holdings thereafter has here been assumed to be the result of no further asset purchases taking place beyond 2022 and all bonds being held to maturity.

We simulate the effects of municipal and covered bond purchases separately, and for the two approaches – A1 and A2 – outlined above.[34] In each case the effects are simulated using the four simulation methods outlined in section 2.3 and for ease of exposition we present the effect averaged across the four methods. The effects of municipal bond purchases are shown in figure 4 and the effects of covered bond purchases are shown in figure 5.

[31] We perform the simulations for the purchases of each type of bond separately, i.e. using QE paths for government, municipal and covered bonds, respectively. Below we add these effects to a total effect of all bond purchases on economic variables. We have verified that the total effects obtained in this way are very similar to those obtained in a simulation with all bond purchases jointly, i.e. using a single QE path capturing the purchases of all three types of bonds.

[32] The interest-bearing debt of issuers of municipal and covered bonds has been collected from the Swedish securities database (SVDB) provided by Statistics Sweden. Only SEK-denominated debt has been included. From 2022 and onwards, this debt is assumed to increase at the long-term growth rate of nominal GDP as defined by the growth of nominal GDP between 2025 and 2026 as projected in the IMF World Economic Outlook October 2021 database.

[33] Following the rapid increase in inflation in 2022, the Riksbank's plan for bond purchases has been somewhat revised in favour of smaller purchases during the second half of the year, implying measures for the Riksbank's holdings of municipal and covered bonds that are 0.5 percentage points lower at the end of 2022 than what is shown in the figure and has been used for our simulations. Accounting for this would not significantly affect our results.

[34] We have two types of bonds (municipal and covered), two approaches (i.e. sets of assumptions) and four simulation methods, which means we perform 16 simulations in total.

Figure 3. The Riksbank's holdings of municipal and covered bonds as a share of the outstanding stock of SEK-denominated central government debt and interest-bearing debt of issuers of municipal and covered bonds. Outcomes for 2020-2021 and projections for 2022 and onwards.

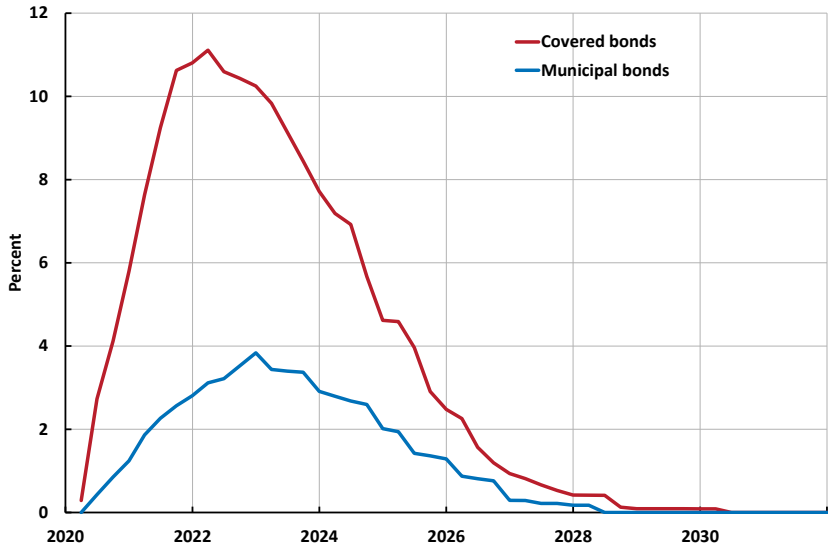
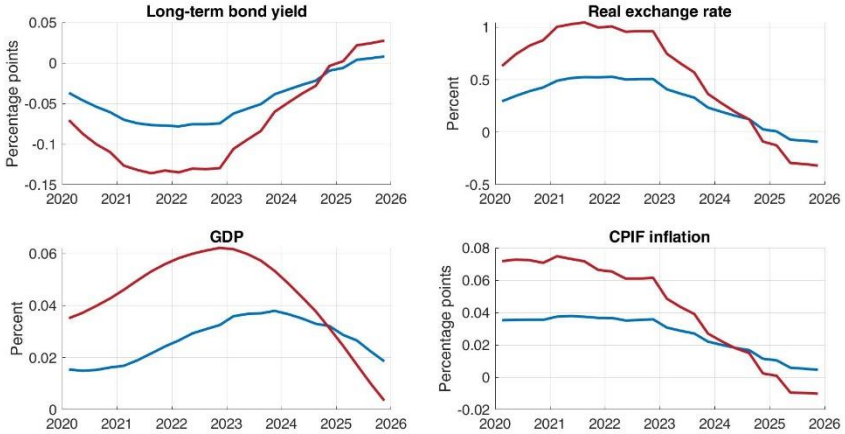
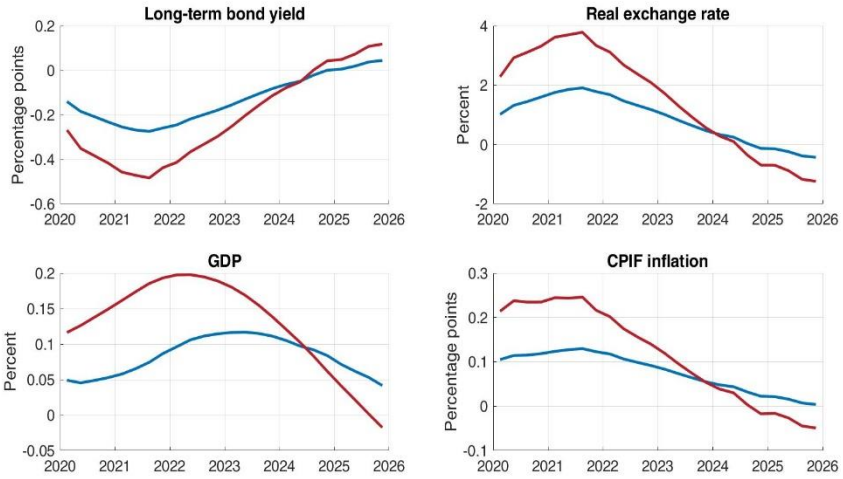


Figure 4. Effects of Riksbank municipal bond purchases: A1 in blue and A2 in red.



Note: The real exchange rate and GDP are in levels and CPIF inflation is in annualised quarterly change. The approaches A1 and A2 are described in section 3.1. The main approach, A1, involves matching the simulated effects of bond purchases on bond yields to the estimated effects in event studies. A2 is a simpler benchmark where it is assumed that a given level of holdings of government, municipal and covered bonds all have the same effects on economic variables as holdings of government bonds in Akkaya et al. (2023).

Figure 5. Effects of the Riksbank's covered bond purchases: A1 in blue and A2 in red



Note: The real exchange rate and GDP are in levels and CPIF inflation is in annualised quarterly change. The approaches A1 and A2 are described in section 3.1. The main approach, A1, involves matching the simulated effects of bond purchases on bond yields to the estimated effects in event studies. A2 is a simpler benchmark where it is assumed that a given level of holdings of government, municipal and covered bonds all have the same effects on economic variables as holdings of government bonds in Akkaya et al. (2023).

For the municipal bond purchases the simulations using approach A1 indicate an average effect on the long-term bond yield of roughly 0.05 percentage points in 2020−2023, and the effect on the real exchange rate is around 0.5 percent.[35] The effects on GDP and inflation are modest – for instance, the average effect on inflation in 2020−2023 is about 0.05 percentage points. With approach A2 these effects are almost twice as large in 2020−2023.

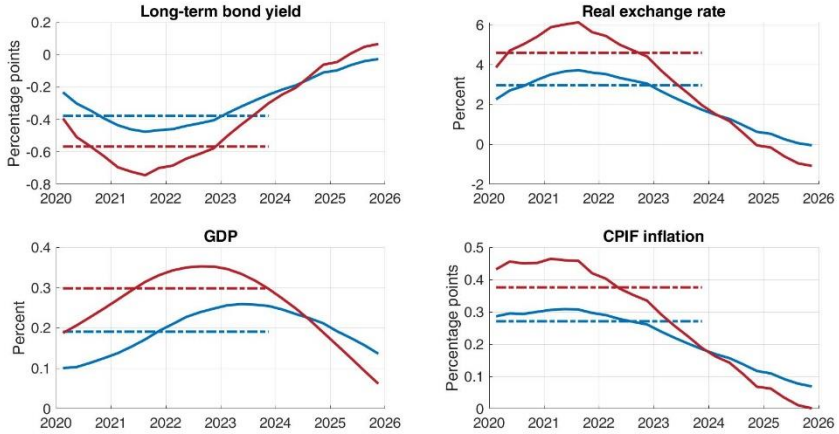
The average effect of covered bond purchases on the long-term bond yield in 2020−2023 with approach A1 equals 0.2 percentage points, while the peak effect on the real exchange rate is close to 2 percent. The effect on GDP in 2020−2023 ranges between 0.05 and 0.1 percent and the average effect on inflation is around 0.1 percentage points. Again, with approach A2 the effects are almost twice as large in 2020−2023.

It is not straightforward how to relate the simulated effects on bond yields to the short-term effects in event studies. We discuss this briefly for the case of covered bond purchases. The near-term effect of covered bond purchases on bond yields derived from event studies is 0.25 percentage points, see table A2 in the appendix. The average effect in 2020−2021, as well as in 2020−2023, for an average of the four simulation methods is 0.2 percentage points. The peak effects of covered bond purchases on bond yields in our simulations range between 0.25 and 0.3 percentage points, where the peak effects occurs immediately when bond purchases are anticipated and in 2021 if they are unanticipated.

[35] We choose to focus on the years 2020−2023 because the effects are largest in this period. If we would only consider the pandemic years 2020−2021 we would miss that the peak effect on GDP in our simulations occurs in 2023.

We conclude by providing an overall assessment of the effects of the pandemic-induced Riksbank asset purchases (see figure 6). Our estimate of the total effects is based on adding the effects of government bond purchases reported in figure 2 in section 2.4 and the effects of municipal and covered bond purchases using approach A1 (see figures 4 and 5). We also show a higher estimate, based on both municipal and covered bond purchases being computed using approach A2.[36] The average effect of the long-term bond rate equals around 40 basis points which is in line with the total effects on 5 year bond yields based on the event study evidence.[37] The average effect on the real exchange rate, GDP and inflation in 2020−2023 equal roughly 3 percent, 0.2 percent and 0.25 percentage points respectively.

Figure 6. Total effects of the Riksbank's purchases of government, municipal and covered bonds during the pandemic: main estimate (blue), higher estimate (red)



Note: The real exchange rate and GDP are in levels and CPIF inflation is in annualised quarterly change. The dashed lines show the average effect in 2020-2023.

Finally, we put our assessed effects of the Riksbank's bond purchases into perspective by comparing them to the evidence on effects of central bank asset purchases gathered from a large number of studies. In 2020−2021 the Riksbank's holdings of government, municipal and covered bonds increased by SEK 560 billion, or roughly 10 percent when expressed as a share of GDP in 2021. A rule-of-thumb based on the empirical effects from many studies suggests that bond purchases amounting to 10 percent of GDP correspond to a decline in 10-year bond yields of around 50 basis points.[38] The effect on the long-term bond yield reported in Figure 6 is broadly in line with this evidence. The effects on GDP and inflation, while arguably small in light of the meta

[36] These effects are very similar to those which would be obtained if one QE path was constructed based on the purchases of all three types of bonds and simulations were performed using the calibration in Akkaya et al (2023). In other words, in approach A2 it does not matter if the effects of bond purchases are simulated separately and then added, or if they are simulated jointly.

[37] See table A2 in the appendix.

[38] See e.g. the studies referenced in Bhattarai and Neely (2022) or Akkaya et al. (2023).

study evidence discussed by Di Casola (2021), are similar to the effects obtained in research which employ a similar type of model featuring asset market segmentation, see Harrison (2011), Chen et al (2012), Burlon et al (2019), Kolasa and Wesolowski (2020) and Alpanda and Kabaca (2020).[39]

4 Conclusion

In this staff memo we simulated the effects of the Riksbank's bond purchases during the pandemic on the Swedish economy, using a slightly modified version of the small open economy DSGE model presented in Akkaya et al. (2023). The model is calibrated to broadly match the effects of bond purchases on bond yields with the evidence from event studies for Sweden. We find that the average effects of bond purchases on GDP and inflation in 2020−2023 equal 0.2 percent and 0.25 percentage points, respectively. Roughly half of these effects are attributed to government bond purchases, and the other half to the purchases of municipal and covered bonds. If we assume that municipal and covered bond purchases have the same effects as government bond purchases the corresponding estimates are 0.3 percent for GDP and 0.4 percentage points for inflation.

To the best of our knowledge, this study is the first to assess the effects of the Riksbank's asset purchases during the pandemic on GDP and inflation. The model used here captures important channels of asset purchases for a small open economy. Furthermore, as shown in Akkaya et al. (2023), the model implications of foreign and domestic central banks' government bond purchases on term premia and capital flows are broadly in line with the data for the pre-pandemic period. However, to the extent that the measures taken by the Riksbank and other central banks in the initial stages of the pandemic contributed to the prevention of a financial crisis, the positive effects on GDP and inflation presented here may be at the lower end of the total effects.

[39] Comparisons with other research requires that the effects are normalised, e.g. that the asset purchases are expressed as a share of GDP and scaled to e.g. one percent of GDP. Di Casola (2021) analyses the evidence collected by Fabo et al (2021) from more than 50 studies of the effects of asset purchases on output and inflation in the United States, the euro area and the United Kingdom. The average peak effect on output from central bank asset purchases amounting to one percent of GDP in these studies equals roughly 0.1-0.4 percent. The maximum effect on inflation equals roughly 0.0-0.2 percentage points. The largest effects of asset purchases are found in studies which focus on the Federal Reserve's large scale asset purchase (LSAP) 1 and 2 programs. There are indications that those programs had substantial signalling effects. Our results are more in line with other studies which apply DSGE models with segmented asset markets such as Chen et al (2012), Burlon et al (2019) and Harrison (2011). One reason why the effects are smaller in this group of studies may be that they have a limited scope for signalling effects that may have played an important role in the early Fed QE programs, see e.g. Krishnamurty and Vissing-Jorgensen (2011). Furthermore, as noted by Bhattarai and Neely (2022), several studies obtain large stimulative effects of QE shocks as a result of combining event-study estimates of QE effects on interest rate spreads with VAR estimates of the effects of reduced interest spreads, therefore capturing the strong countercyclicality of such spreads.

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APPENDIX

Calibration

In table A1 we collect the parameters which have been re-calibrated as compared to the calibration in Akkaya et al (2023). The transaction cost of bonds parameter governs the elasticity of the term premium with respect to central bank bond purchases. We have performed sensitivity analyses to investigate if re-calibration of other parameters affects the simulation results. The parameters analysed include the duration of bonds in the large economy, the share of long-term debt in the stock of debt in both economies, and the share of resident holdings of bonds issued by the small economy. Since re-calibration of these parameters have very small effects on the results, we choose to keep their values as in Akkaya et al. (2023).

Table A1. Key debt related parameters

Parameter	Government bond calibration, Akkaya et al (2023).	All bonds calibration
Debt to GDP, Sweden*	0.25	0.95
Debt to GDP, foreign economy*	0.62	0.98
Duration, long-term debt, quarters	24	16
Transaction cost of bonds	0.015	0.01

Note: Debt refers to central government debt (including the central bank) in the government bond calibration. In the all bonds calibration it also includes municipal bonds and covered bonds, as well as short-term interest-bearing debt instruments issued by the same entities. Parameters marked with asterisks (*) are steady state ratios. The government bond calibration is presented and discussed in detail in Akkaya et al (2023).

The main approach for computing the effects of municipal and covered bond purchases – approach A1

We compute the effects of the purchases of government, municipal and covered bonds separately to allow for the possibility that they may have different effects on the economy. For each type of bond we aim to match the effect of the purchases on bond yields reported by Gustafsson (2022), which are obtained using an event study approach. However, these effects are obtained based on the joint announcements of purchases of the different type of bonds, making it difficult to decompose the effects on bond yields into contributions from purchases of the different types of bonds. In order to perform such a decomposition we make additional assumptions, which are discussed below. We note that the empirical effects of purchases on bond yields, and the decomposition into contributions from purchases of different types of bonds are very uncertain. Still, specific assumptions need to be made and we will now spell them out in detail

In the row ‘total’ in table A2 we reproduce the total effects on 5-year government, municipal and covered bond yields of the Riksbank’s asset purchases announced in

2020 reported by Gustafsson (2022).[40] The numbers reported in parentheses are the effects on risk premia, i.e. the difference between the bond yield and the government bond yield. Our objective is to attribute these effects on yields to the Riksbank's purchases of the different bonds.

We note that the effects of the pandemic bond purchases on municipal and covered bond risk premia are clearly negative, they both decline by 34 basis points. This contrasts with the positive effects on covered bond risk premia of the Riksbank's pre-pandemic government bond purchases reported by Melander (2021) where government bond yields fell more than covered bond yields. It appears likely that this conspicuous difference is simply due to the fact that the pandemic purchases involved purchases of municipal and covered bonds, while the pre-pandemic purchases only involved government bonds. A similar observation was made by Krishnamurthy and Vissing-Jorgensen (2011) regarding the different effects of the Federal Reserve's QE1 and QE2 programmes on mortgage rates.[41]

We first discuss the decomposition of the effect on the government bond yield into contributions from purchases of the three types of bonds. In section 2.4 we obtained the effects of the pandemic government bond purchases and concluded that roughly half of the total effect on the government yield is accounted for by the purchases of government bonds.[42] Hence the other half is assumed to be accounted for by the municipal and covered bond purchases. We further assume that municipal and covered bond purchases are equally effective and attribute their contribution to the decline in the government bond yield in proportion to their shares in the Riksbank's holdings.[43] This provides us with the decomposition of the effect on the government bond yield in column a. in table A2.

Next we consider the effect of government bond purchases on the yields of the different bonds (row i in table A2). We assume that these purchases only affect the risk-free component of the municipal and covered bond yields, which appears to be broadly in line with evidence on the effects of the Riksbank's government bond purchases on covered bond yields before the pandemic.[44] Hence we assume that the government bond purchases affected interest rates broadly. In line with this assumption

[40] These effects consist of the effects of the three announcements in 2020 and extrapolated effects in order to obtain the total effects of bond purchases, see Gustafsson (2022). The effects on government bond yields reported here are the effects on the yield spread against Germany.

[41] The QE1 programme involved large purchases of agency mortgage-backed securities (MBS), while QE2 involved only Treasury purchases. In their event study Krishnamurthy and Vissing-Jorgensen (2011) find that QE1 reduced MBS rates substantially while QE2 had smaller effects.

[42] This was in turn based on the assumption that the effectiveness of government bond purchases during the pandemic equalled the effectiveness prior to the pandemic, i.e. the purchases in 2015-2019.

[43] We have relied on the fact that on average, the projected Riksbank holdings of covered bonds are four times larger than those of municipal bonds.

[44] Melander (2021) study the effects of the Riksbank's announcements of government bond purchases in 2015-2017 on various financial variables. The reported total effects on 2 year government and covered bond yields are −31 and −30 basis points respectively and the corresponding effects for the 5 year bond yields −45 and −33 basis points. This suggests that the purchases mainly affected the risk-free component of the covered bond yield, while the risk premium was largely unaffected. Similar results are obtained by D'Amico and Kaminska (2019) who show that the pass-through of Bank of England gilt purchases on corporate bond yields is significant and is often limited to the default-free component of the corporate yields.

we further assume that the covered bond risk premium, i.e. the spread between the covered and government bond yields, is only affected by covered bond purchases and similarly we assume that the municipal bond risk premium is only affected by purchases of municipal bonds.[45] We note that, according to the results from the event studies, the reduction of covered and municipal bond risk premia accounted for a large share of the overall decline in their yields. Our assumption therefore implies that a large share of the decline in covered bond yields is attributed to purchases of covered bonds (and similarly for municipal bonds). While the municipal and covered bond purchases are assumed to have had some effects on government bond yields, with our assumptions they mainly affected their own risk premia.[46]

Table A2. Near-term effects of bond purchases on 5-year bond yields

	Effect on 5-year bond yield, basis points			
	a. Government	b. Municipal	c. Covered	Average bond yield
Bond purchased				
i. Government	−8	−8 (0)	−8 (0)	−8
ii. Municipal	−2	−36 (−34)	−2 (0)	−7
iii. Covered	−5	−5 (0)	−39 (−34)	−25
Total	−15	−49 (−34)	−49 (−34)	−40
Share of bonds	25%	15%	60%	100%

Table A3. Near-term effects of bond purchases on 2-year bond yields

	Effect on 2-year bond yield, basis points			
	a. Government	b. Municipal	c. Covered	Average bond yield
Bond purchased				
i. Government	−5	−5 (0)	−5 (0)	−5
ii. Municipal	−1	−15 (−14)	−1 (0)	−3
iii. Covered	−4	−4 (0)	−18 (−14)	−12
Total	−10	−24 (−14)	−24 (−14)	−20
Share of bonds	25%	15%	60%	100%

Note to tables A2 and A3: The table decomposes the effect of bond purchases on government, municipal and covered bond yields into contributions from purchases of the different types of bonds. The total effects on the government, municipal and covered bond yields and risk premia are taken from Gustafsson (2022). The assumptions underlying the decomposition are described in the text. The numbers in parentheses are effects on bond risk premia, i.e. the spread on the government bond yield. The effect on the average bond yield is obtained as the weighted average of the effects on the different yields, where the weights are provided in the bottom row of the table.

Finally we obtain the effect of the purchases of each type of bond on a weighted average of the bond yields, where the weights are their shares of the outstanding stock of government, municipal and covered bonds.[47] For simplicity we refer to this weighted average as the *average bond yield*. This could be interpreted as a proxy for the effects

[45] This could also be said to be in line with the evidence in D'Amico and Kaminska (2019). They find that credit easing is more effective than quantitative easing in reducing credit spreads.

[46] Gustafsson and von Brömsen (2021) distinguish between broad and targeted purchases. Based on the effects on bond yields assumed here government bond purchases are broad while municipal and covered bond could be characterised as more targeted measures.

[47] The shares of government, municipal and covered bonds in the stock of these bonds are 25, 15 and 60 percent, respectively.

of the purchases on the general level of interest rates in the economy, i.e. the interest rates facing households and companies. Since government bond purchases are assumed to affect interest rates broadly their effect on the average bond yield is the same as their effect on government bond yields. The effects of municipal and covered bond purchases on the average bond yield are instead smaller than the effects on their own bond yields.

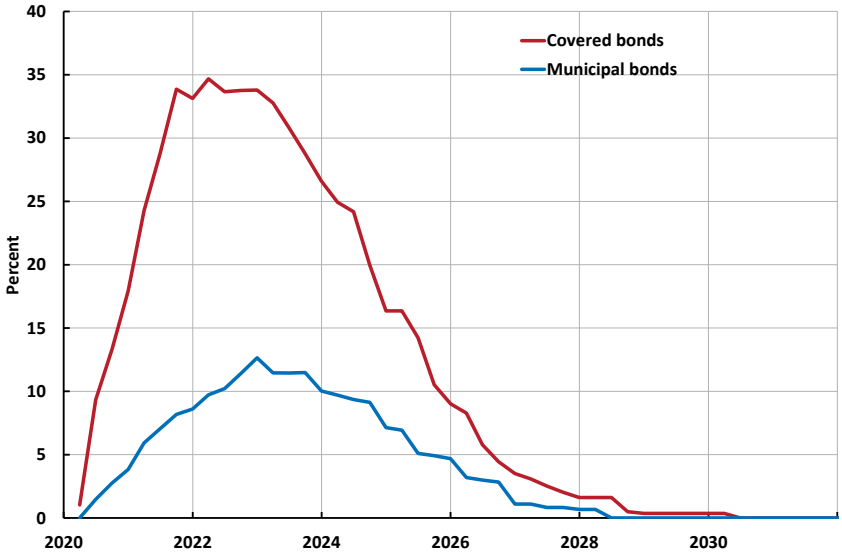
In the model simulation we aimed at matching the average effects of the covered bond purchases on the long-term bond yield in 2020-2021.[48] Above we considered the effects of bond purchases on 5-year bond yields. But the average duration of municipal and covered bonds purchased by the Riksbank equals roughly 3 years. We therefore also produce a decomposition of the effects of the purchases on 2-year bond yields. This is shown in table A3 and it is based on the same assumptions and reasoning as for the 5-year bond yields. The effect of covered bond purchases on the average 2-year bond yield equals −12 basis points, that is roughly half of the corresponding effect on the average 5-year bond yield. For the covered bond purchases it therefore appears reasonable to target a near term effect on the long-term bond yield in the model simulation of 15−20 basis points, reflecting an average of the effects on 2- and 5-year yields. A similar relationship between the effects on average 2- and 5-year bond yields holds for the municipal bond purchases and here it appears reasonable to target a near-term effect on the long-term bond yield in the model around 5 basis points. To achieve these effects of bond purchases on yields in the model we calibrate the value of the parameter which governs the effect of bond purchases on long-term bond yields (the transaction cost parameter reported in table A1) to be somewhat lower than the value used by Akkaya et al. (2023). The approach outlined above is denoted A1.

The re-calibrated model implies that purchases of municipal and covered bonds are treated as less effective than purchases of government bonds. This means that purchases of a given SEK amount of these bonds have smaller effects on the economy than purchases of the same amount of government bonds. Given the uncertainty regarding the cited empirical evidence, we contrast it with other approaches. We also report effects obtained when we instead assume that the effects of the purchases of municipal and covered bonds are equal to the effects which would have been obtained if the Riksbank had instead purchased government bonds of the same nominal value.[49] We then apply the approach in Akkaya et al. (2023), which was described above in section 2, to compute these effects – in particular we use the calibration in that paper to compute the effects. We call this approach A2. The QE paths used for these simulations are shown in figure A1.

[48] It is not obvious how to relate the instantaneous effects on financial prices in event studies to the simulated effects over a longer period in the model. We choose to contrast the event study effects to the average effect on the bond yield in 2020-2021.

[49] One could put forth an argument that the effects of purchases of municipal and covered bonds ought to be quite similar to those we have calculated for the purchases of government bonds on account of the three types of bonds being close substitutes.

Figure A1. The Riksbank's holdings of municipal and covered bonds as a share of the outstanding stock of central government debt. Outcomes for 2020-2021 and projections for 2022 and onwards. These paths are used to simulate effects of bond purchases with approach A2.



Simulation results

In figures A2 to A6 we show the results of the simulations using the four methods described in section 2.3. The assumptions underlying these methods are summarised below.

- Anticipated: the entire QE path is anticipated by the agents in the economy.
- Unanticipated: at each point in time agents anticipate that the central bank holdings of bonds as a share of the stock of bonds will stay (approximately) unchanged.
- Forward guidance: agents anticipate that the policy rate will stay constant for 4 quarters.
- No forward guidance: the policy rate reacts endogenously to QE.

In these figures the real exchange rate and GDP are in levels and CPIF inflation is in annualised quarterly change.

Figure A2. Effects of Riksbank government bond purchases during the pandemic

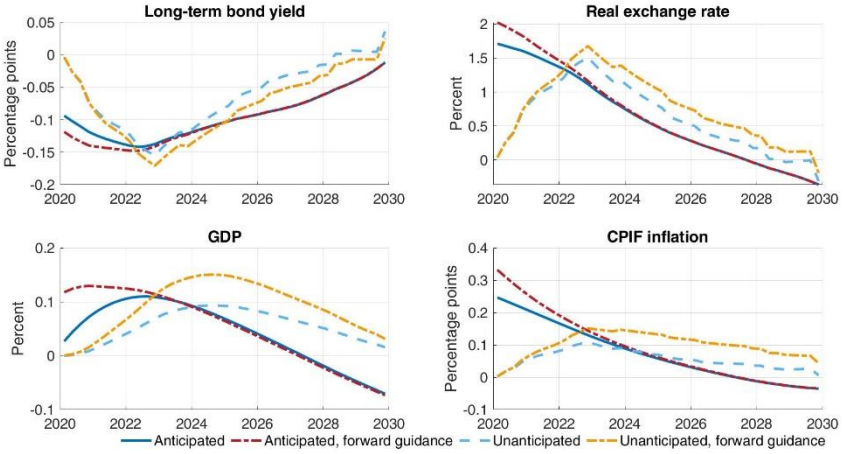


Figure A3. Effects of Riksbank municipal bond purchases during the pandemic, approach A1

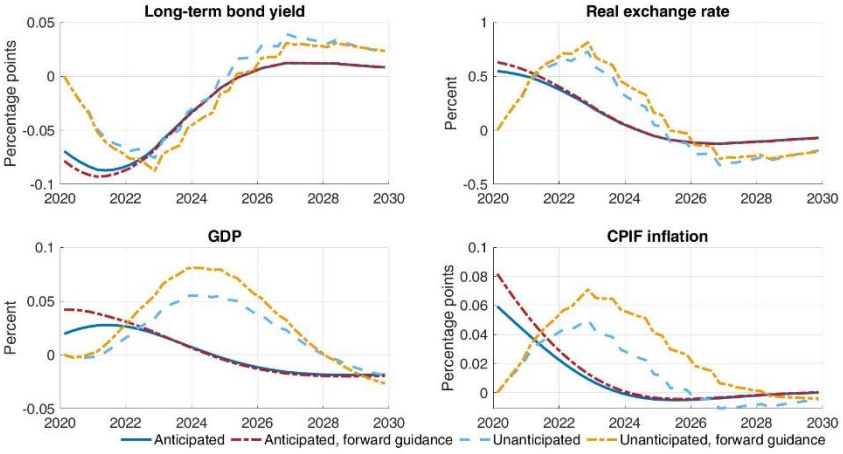


Figure A4. Effects of Riksbank municipal bond purchases during the pandemic, approach A2

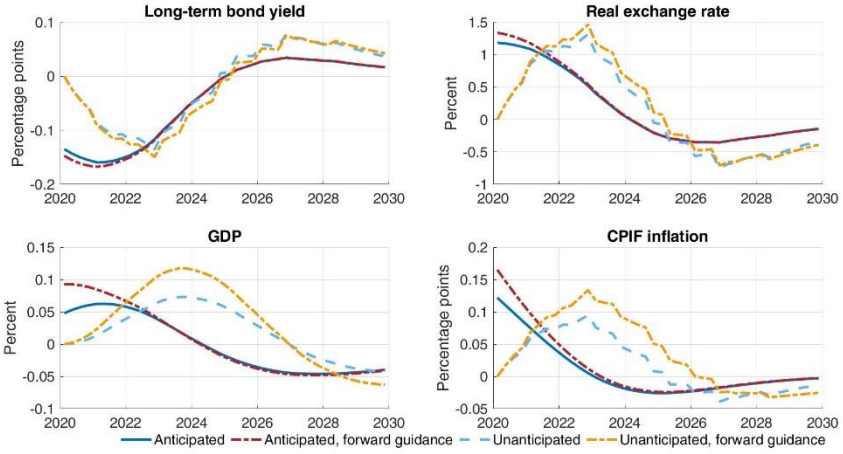


Figure A5. Effects of Riksbank covered bond purchases during the pandemic, approach A1

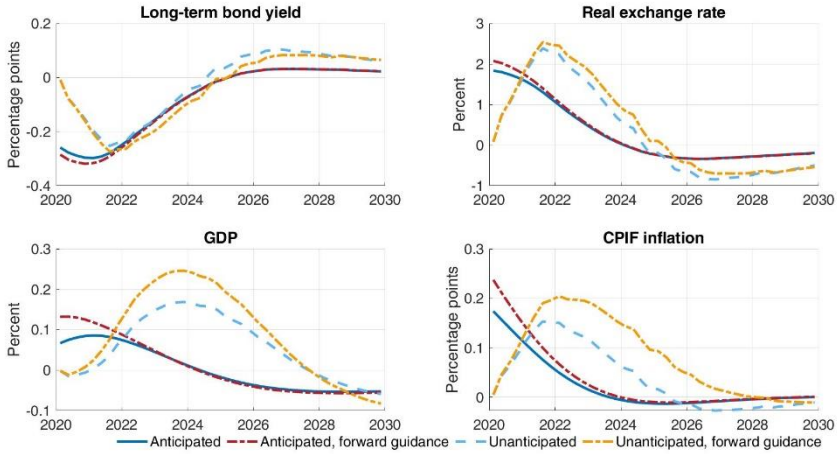
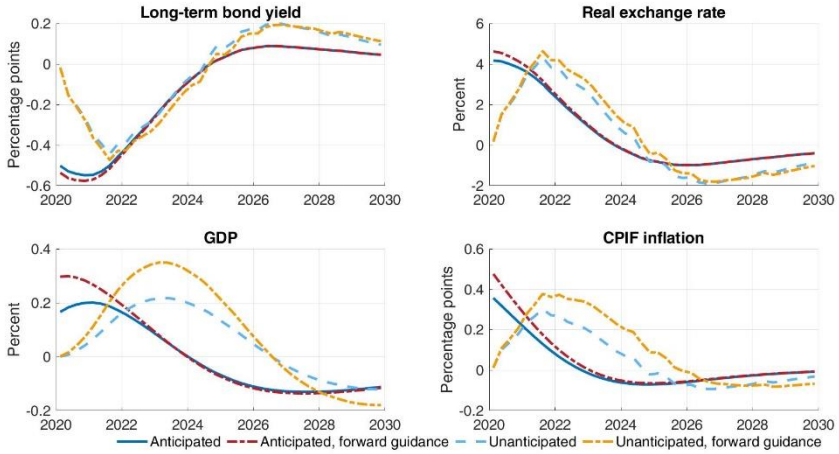


Figure A6. Effects of Riksbank covered bond purchases during the pandemic, approach A2



Uncertainty

The DSGE model is calibrated, hence we do not take into account parameter uncertainty (e.g. through a posterior distribution obtained using Bayesian estimation of the model). In our two approaches (section 3.1) and simulation methods (section 2.3) we consider uncertainty about

- The effects of bond purchases on interest rates and other variables (framed in terms of parameter uncertainty through a re-calibration of the model.)
- The agents' expectations of QE and policy interest rates.

Since it is difficult to make probabilistic assessments of the assumptions, we choose not to report uncertainty intervals for the effects. However, the reported results of the individual simulations makes it possible to study how the different assumptions affect the results, see figure A1 to A6.

SVERIGES RIKSBANK
Tel 08 - 787 00 00
registratorn@riksbank.se
www.riksbank.se

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