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Unconventional Monetary Policies in Small Open Economies

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ABSTRACT: This paper provides a comprehensive assessment of the macroeconomic and fiscal impact of unconventional monetary tools in small open economies. Using a DSGE model, we show that the exchange rate plays a critical role to amplify the favourable impact of unconventional monetary policy while it attenuates the effectiveness of conventional fiscal policy to jointly boost output and inflation. We then use the model as a laboratory to do a case study of the Swedish Riksbank asset purchases and negative policy rates 2015-2019. We find that the Riksbank unconventional policy measures provided meaningful macroeconomic stimulus to economic activity and inflation, with the dual benefit of reducing overall government debt by about 5 percent of GDP. If conventional fiscal policy had been used to provide a commensurate output boost, inflation would have risen notably less, and the fiscal cost would have amounted to a deterioration of the government debt position with nearly 8 percent of GDP.

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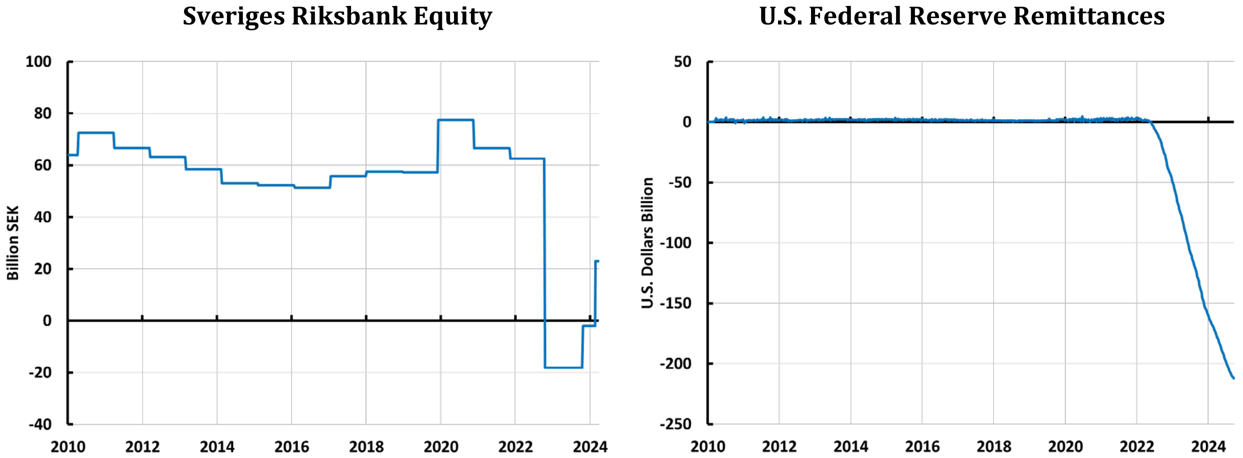
1. Introduction

Following the Global Financial Crisis and the Euro area debt crisis, central banks ventured into unprecedented territory, deploying unconventional monetary policy (UMP) tools – including large scale asset purchases (LSAP), negative policy rates, and forward guidance – to stimulate economic activity, bring inflation closer to target, and reduce the risk of deflationary spirals. For instance, the Swedish Central Bank (Sveriges Riksbank), cut their policy rate into negative territory and began to undertake large scale assets purchases in early 2015. Of these unconventional policy measures, especially asset purchases have been considered controversial as many observers claim they blur the line between monetary and fiscal policy. They also subsequently led to substantial central bank balance sheet losses during the Post-COVID inflation surge as shown in Figure 1. This has led to vibrant debate of the macroeconomic benefits and the fiscal costs of unconventional monetary interventions. [1]

Figure 1. Sveriges Riksbank Equity and Federal Reserve System Earnings Remittances Due to the U.S. Treasury.



Note: The right panel illustrates that the Federal Reserve's costs began surpassing its income in September 2022, following the sharp increase in policy rates and the corresponding rise in interest expenses. Note that this data series represents a flow when positive but reflects a stock when negative. Specifically, when the Fed's net income is positive, the series shows the weekly amount remitted to the U.S. Treasury. Conversely, when net income is negative, the series records the value of the deferred asset, representing the cumulative total of the Fed's negative net income. As the Federal Reserve returns to profitability, it reduces its deferred assets until they are fully paid off, after which it resumes remittances to the Treasury. Source: Sveriges Riksbank and Board of Governors of the Federal Reserve System (US), Liabilities and Capital: Liabilities: Earnings Remittances Due to the U.S. Treasury: Wednesday Level [RESPPLLOPNWW], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/RESPPLLOPNWW.

The Riksbank's experience with these policies offers a stark illustration of the challenges of using unconventional monetary tools to meet inflation targets in a small open economy. By April 2024, the Riksbank's balance sheet had absorbed substantial losses from its LSAP program, prompting a petition to the

[1] Data from the Federal Reserve, the Eurosystem, and the Bank of England indicate that their maximum annual losses range between 0.3% and 1.5% of GDP. The European Central Bank (ECB) reported a net loss of €1,266 million in its 2023 audited financial statements, a sharp contrast to its break-even result in 2022. This loss will be carried forward and offset against future profits. To mitigate the impact, the ECB fully released its €6,620 million provision for financial risks, resulting in no profit distribution to euro area national central banks (NCBs) for 2023. Note that the timing and distribution of these losses may vary across the Eurosystem due to differences in national accounting rules. See also Table 1 in IMF (2024).

Swedish parliament for a capital injection of SEK 43.7 billion (approximately 0.7 percent of 2023 nominal GDP) to restore a positive level of capital of the central bank (see Figure 1).[2] Adding to this, the Swedish National Audit Office (2023) (RiR) and the Swedish Treasury Long-Term Survey "SOU 2023:85" criticized the Riksbank unconventional monetary policies on two grounds. First, they argued that they had been ineffective to stimulate economic activity and inflation. Second, they noted that the policies had led to large central bank balance sheet losses, which puts upward pressure on the consolidated government debt position. All told, the Swedish RiR recommended against future use of LSAPs as an inflation-targeting tool.

Against this backdrop, this paper aims to enhance the understanding of the macroeconomic and fiscal implications of unconventional monetary policies. Building on the closed economy results in Adrian et al. (2024), it reevaluates these policies in a small open economy framework, with a particular focus on the exchange rate channel as a key propagation mechanism. The fiscal consequences of unconventional monetary easing tools, like LSAPs, are more complex than those of conventional rate cuts. Conventional monetary easing, primarily through reductions in policy interest rates, typically bolsters the fiscal position by stimulating economic growth, raise tax revenues, and by lowering government debt servicing costs.[3] This approach also has a minimal impact on central bank balance sheets. In contrast, LSAPs can strain central bank finances. These purchases expose central banks to potential capital losses and higher funding costs if interest rates rise. However, LSAPs can also have positive fiscal effects—such as influencing asset prices and rates of return—potentially boosting economic activity and tax revenues.

Assessing the fiscal costs and benefits of unconventional monetary policy tools necessitates taking a stand on the efficacy of LSAPs as a means to stimulate output and inflation, particularly outside periods of acute financial instability. A recent meta study by Fabo et al. (2021) review research by academics and central banks on the effects of balance sheet policies in the euro area, the United States and the United Kingdom. The studies by non-central bank researchers reviewed by Fabo et al. suggest that LSAPs equal to 10% of the respective country's GDP results in a peak impact on output of 1.1 percent, which is notably lower than that reported by researchers at central banks. While the estimated effects in various studies can differ due to different monetary policy frameworks, the duration of the effective lower bound on short-term policy rates, the pre-LSAP level of the term-premium, the way the financial markets function, the way the central banks have designed their

[2] In terms of 2014 nominal GDP the petition amounts to 1.1 percent. As stipulated by the Sveriges Riksbank Act, the Riksbank must submit a request to the Riksdag for an equity restoration if its equity drops below the required minimum level. Following the 2023 financial statements and profit appropriation, the Riksbank's equity fell below this threshold. Consequently, in spring 2024, the Riksbank submitted a request to the Riksdag to increase its capital. In June, the Riksdag approved a capital injection of SEK 25 billion (0.4 percent of 2023 nominal GDP), and the Government has authorized the payment. This capital injection will raise the Riksbank's equity to SEK 23 billion. In December 2024, the Riksdag decided to change the Riksbank's authority to propose equity restoration from an obligation to an option. Additionally, it amended the Sveriges Riksbank Act, allowing the Riksbank to require credit institutions to hold interest-free deposits when its equity falls below the target level.

[3] While monetary easing typically strengthens the fiscal position, the extent of this effect depends on the fiscal framework in place. We assume through the paper in the terminology of Leeper (1991) that monetary policy is active, i.e. satisfies the Taylor (1993) principle, and that fiscal policy is passive, i.e. fiscal instruments are used to eventually stabilize debt around a desired level.

purchase programmes, or simply by which method has been used to estimate the effect, we take a conservative view on the transmission of LSAPs by calibrating the model towards the lower end of the estimates. By design, the purchases we consider build in a gradual unwind of the central bank's holding of long-term assets. Exactly how long time it takes for the central bank balance sheet to normalize depends on the maturity structure of purchased assets. Hence, the LSAPs we consider has a QE phase followed by a more gradual quantitative tightening (QT) phase.

An important additional consideration when analysing the macroeconomic transmission of LSAPs is the larger incidence of short-term borrowing (or long-term borrowing at a variable rate), which is often argued to limit the economic effects of LSAPs in small open economies like Sweden relative to the United States when financial markets are not disrupted. The straightforward argument behind this reasoning, advocated by Flodén (2022) and Swedish National Debt office (2023), is that the transmission of lower long-term interest rates in stimulating demand is weak (or even absent) when household and corporate decisions are primarily influenced by current and expected short-term rates. A closed economy formulation of our quantitative model is consistent with this thinking and delivers negligible effects of LSAPs when all agents have access to short-term bonds and hence can arbitrage away the differences between long and short-term yields. In this case, asset purchases compress long-term yields, but leave private spending unaffected as it is dictated by the current and expected short-term policy rate path.

In contrast, an open economy formulation of the model implies that LSAPs can influence economic activity via the exchange rate channel, which operates even if the bond market is not segmented domestically. For small open economies like Sweden, LSAPs lower domestic long-term rates relative to foreign rates, which weakens the exchange rate. This depreciation enhances export competitiveness and supports inflation, illustrating the broader macroeconomic impacts of LSAPs beyond domestic financial conditions. Hence, while the direct effects of LSAPs on household and corporate borrowing decisions may be limited, the exchange rate channel plays a crucial role in providing some modest impact on economic activity of LSAPs. By reducing term premiums and long-term interest rates, and depreciating the exchange rate, we show that LSAPs provide limited yet meaningful macroeconomic boost to demand and inflation in an open economy framework.

Interestingly, we document that LSAP, i.e. purchases of domestic long-term government bonds paid for by issuing short-term central bank reserves, has nearly the same impact as purchases of foreign long-term bonds (again paid for by issuing reserves).[4] This is a direct consequence of a "long" Uncovered Interest Parity holding in our model, in line with empirical evidence for advanced economies discussed by Lustig et al. (2019), implying that domestic bond and FX markets are tightly connected. Hence, if the supply of domestic long-term government bonds is thin, the small open economy central bank can stimulate the economy by purchasing foreign long-term bonds. This highlights the critical role of the exchange rate and the similarity between LSAP

[4] As the latter is often referred to as a form of FX intervention, our model carries the implication that an FX intervention may have very similar effect as LSAPs under some circumstances. We expand on this point in Section 3.

and "foreign exchange interventions" in our open economy framework, supporting the argument in Cwik and Winter (2024). Notably, this similarity suggests that LSAPs can serve as a close substitute for Svensson's (2003) 'foolproof' method for escaping a liquidity trap.

The other key unconventional monetary policy tool is negative interest rate policies (NIRPs). Several leading central banks, including the European Central Bank, the Riksbank, and the Swiss National Bank employed NIRPs alongside LSAPs to stimulate economic activity amid persistently below-target inflation readings. However, NIRPs have faced criticism regarding their effectiveness and unintended consequences. While, for instance, Brandao Marquez et al. (2021) suggest that NIRPs maintain effective transmission to lending rates other studies, notably Eggertsson et al. (2024) find a diminished pass-through effect on mortgage lending rates on Swedish data. We expand the focus to the broader effects of NIRPs across the economy and find no evidence against the null hypothesis of unchanged transmission of mildly negative policy rates on Swedish data during the episode with negative rates. Hence, in our analysis we just impose a negative ELB and assume that the transmission of unanticipated short-term policy rate changes is similar when policy rates are positive or (moderately) negative. Appendix 1 provides empirical evidence that justifies this assumption.

In the second part of the paper, we assess the fiscal and economic implications of the Swedish Riksbank unconventional monetary policies between 2015 and 2019 with our structural macroeconomic model. We stop before the COVID pandemic as this episode may not be well captured with the model. After careful calibration to align the transmission of the key policy tools – NIRPs, LSAPs and government spending – with empirical studies for Sweden, we use the model to simulate the impact of the Riksbank unconventional policy measures that were implemented at a juncture when inflation had been running persistently below target for some time, raising concerns about de-anchoring of inflation expectations. We calculate these measures from announcements in Riksbank monetary policy reports and hence maintain the assumption that they are discretionary actions by the central bank.[5] A structural modeling approach is essential as it allows us to create a counterfactual scenario in which the Riksbank communicated that it was not possible to cut short-term policy rates below zero and abstracted from LSAP. An additional advantage with a structural modeling approach is that it allows us to calculate the effects on a broad set of macroeconomic and fiscal variables when imposing stock-flow consistency. Our analysis does not include the spillovers from UMPs by other major central banks.

The specific model we use is an open economy formulation of the Adrian et al. (2024) model. This model adds discounting following Gabaix (2020) and Kolasa et al. (2025), kinked demand and nonlinear Phillips curves as in Harding et al. (2022, 2023), habit formation in consumer preferences, and sticky wages following Erceg et al. (2000) into the Kolasa and Wesołowski (2020) model. We show that the real exchange rate channel is a key transmission channel of LSAPs in open economies, and our calibration of the model implies that the impact

[5] In December 2014, at the time of the monetary policy update, market pricing of the repo rate aligned with the Riksbank's forecast until autumn 2016, when the projected repo-rate path signaled the first rate hike. Notably, markets never anticipated negative policy rates. In the monetary policy report in October 2014, the Riksbank noted it did not see a need for asset purchases but remained prepared to act if necessary.

of LSAP is even weaker than the estimates by academic researchers in the survey by Fabo et al.'s (2021). Hence, our aim is to provide a conservative macroeconomic and fiscal impact assessment of this unconventional policy. For short-term policy rate cuts and conventional fiscal expansions through higher government spending, the model is calibrated to be well in line with estimates in the international literature, taking into account recent findings on the transmission of fiscal policy in open economies. Applying calibrated budget elasticities for Sweden allows us to translate policy-driven changes in economic activity and inflation into measurable impacts on tax revenue and debt.

We also use the model to do a counterfactual scenario assessing that would have happened if fiscal stimulus – in the form of higher government consumption spending – had been adopted instead of the Riksbank unconventional policy measures. We normalize the fiscal stimulus so that it achieves the same path of economic activity (output) as the Riksbank unconventional policy measures delivered. We can then compare the differences in propagation to other key macro variables – such as core CPI inflation and the real exchange rate – and assess the fiscal implications of the alternative means to provide economic stimulus during this episode.

While there is an extensive literature on conventional and unconventional policies on Swedish data, only one study, to our knowledge, uses a structural model to analyze the dynamic economic impacts of such interventions for Sweden.[6] And none of these studies have assessed the fiscal consequences of the Riksbank unconventional policy measures and compared them with those arising if conventional fiscal stimulus had been used instead.

Interestingly, our Swedish case study finds that unconventional monetary measures deployed by the Riksbank had almost indiscernible impact on output growth and core inflation (annualized quarterly growth rates) from one policy round to another (i.e. quarter by quarter), as these tools were gradually expanded in an unanticipated fashion over time. While these interventions raised bond prices and lower term premiums, the immediate short-term stimulus to output and inflation was very small, consistent e.g. with event studies of Swedish LSAPs. See Andersson et al. (2022) and papers cited therein.[7]

Nevertheless, although the near-term effects of the sequential policy measures are minor, the Riksbank unconventional measures generate significant accumulated effects over time. For example, we find that UMP stimulated output by about 1 percent 2016-2018 and increased inflation by 0.4 percentage points in 2016. As intended, they also led to a significant persistent depreciation of the real exchange rate of about 5 percent. As

[6] To illustrate the breadth of this research, some notable contributions include the following studies: Alsterlind, Erikson, Sandström, and Vestin (2015), De Rezende, Kjellberg, and Tysklind (2015), De Rezende (2017), Alsterlind (2021), Blix Grimaldi, Crosta, and Zhang (2021), Di Casola (2021), Gustafsson (2022), Gustafsson and von Brömsen (2021), Di Casola and Stockhammar (2021), Erikson (2021), Hansson and Birging (2021), Melander (2021), Andersson, Beechey Österholm, and Gustafsson (2022), Beechey Österholm (2022), Akkaya, Belfrage, Di Casola, and Strid (2023 a, b), De Rezende and Ristiniemi (2023).

[7] This minor impact effect highlights the challenges of event studies to evaluate the effects of UMPs.

explained earlier, the weaker exchange rate accounts for the bulk of the positive output and inflation impetus in our analysis. And local projection evidence that we provide in Appendix 3 supports this model mechanism by establishing that a weaker exchange rate leads to a sustained increase in Swedish net exports. It is important to note that this assessment of transmission is conservative as we assume a limited impact of LSAP and use a nonlinear model which implies that the Phillips curve is flatter when inflation is low (and LSAPs were undertaken by the Riksbank). We also do not allow for LSAPs to serve as a signaling tool that provides additional forward guidance on lower-for-longer short-term policy rates paths.

Taken together these policy measures led to an improvement in the consolidated public sector's fiscal position by about 5 percent of GDP. That is, government debt would have been about 5 percent of GDP higher by the end of 2019 had the Riksbank not adopted these unconventional policy tools 2015-2019. These gains to the fiscal balance by end-2019 outsize the Riksbank's subsequent balance sheet losses in 2022 several times. Hence, we do not need to study the LSAPs during the COVID pandemic to be able to conclude that the Riksbank's unconventional measures 2015-2021 significantly benefitted the consolidated government debt position. Even so, while the ex post fiscal gains have been substantial according to our analysis, LSAPs are associated with notable ex ante risks for the central bank balance sheet and may also carry risk for the consolidated fiscal position as discussed in detail in Adrian et al. (2024). It is also possible that LSAPs (and negative rates) could lead to a buildup of financial vulnerabilities that make the economy more exposed to adverse risks down the road as argued by Acharya et al. (2024).

In the counterfactual scenario, where conventional fiscal stimulus replaces the Riksbank's unconventional policy measures, we find that achieving the same path of output stimulus results in significantly higher fiscal costs. Increased public spending or tax cuts widen the budget deficit and worsen the public debt position. Additionally, fiscal stimulus in isolation has a less favorable impact on inflation as the currency appreciates, which reduce the inflationary effects that UMP achieves through exchange rate adjustments. This finding underscores that while fiscal policy is a viable tool to stimulate output – especially if applied without delay – it may be eventually less effective than UMP in achieving higher inflation and is more likely to carry a notably more expensive fiscal bill.

The remainder of the paper is structured as follows: Section 2 describes the model, including how it is calibrated and solved. In Section 3 we provide an in-depth discussion of how the transmission of the three policy instruments we consider depends on the exchange rate channel and the degree of openness in the economy. Next in Section 4 we report the design and results of the case study we do for the Riksbank unconventional monetary policy stimulus during 2015-2019 and compare outcomes with an alternative policy mix where fiscal policy is calibrated to achieve the same output boost via higher government spending. Finally, we provide some concluding remarks in Section 5. Appendices 1 and 2 contain some additional results.

2. The Quantitative Model

The quantitative model builds on Kolasa and Wesołowski (2020), Erceg et al. (2024), and Adrian et al. (2024). Compared to a standard DSGE model, our framework includes the following key features. First, we introduce bond market segmentation, following the approach of Andres et al. (2004), Chen et al. (2012), and Kiley (2014). This means that short- and long-term bonds are imperfect substitutes, allowing central bank asset purchases to influence term premiums and have real economic effects. As in Kolasa and Wesolowski (2020), we assume that long-term bonds can be traded internationally, which ensures that term premiums affect the exchange rate even if all domestic agents can arbitrage between short- and long-term bonds. Second, we incorporate a moderate degree of cognitive discounting, in line with Gabaix (2020), to address the forward guidance puzzle (see Del Negro et al., 2012). This necessitates the use of additional policy tools, such as asset purchases or fiscal expansion, when the policy rate is constrained by the effective lower bound. Third, we include strategic complementarities in price setting, which reduces the sensitivity of inflation during recessions (the missing deflation puzzle) and explains its sharp rise during rapid recoveries (see Harding, Lindé, and Trabandt, 2022; 2023).

As in Adrian et al. (2024), we introduce two further modifications to ensure an empirically realistic transmission of both monetary (interest rate and asset purchases) and fiscal (government consumption) policy shocks. First, we incorporate habit formation in consumer preferences to generate a gradual and hump-shaped output response to a short-term interest rate cut. Since the model is primarily Ricardian and lacks endogenous capital formation, habit formation helps mitigate the crowding out of private spending following an increase in government consumption, better aligning the model with empirical evidence on fiscal policy's effects on output. Second, we allow for gradual nominal wage adjustment to temper inflation responses and produce more realistic wage and profit dynamics, consistent with Christiano, Eichenbaum, and Evans (2005) and Bilbiie and Trabandt (2024). These two adjustments are critical for capturing the fiscal revenue response, which primarily depends on proportional taxation of consumption and labor income, in reaction to shocks and policies. Since we focus on LSAPs and negative rates outside of episodes with acute financial stress, we abstract from Bernanke, Gertler and Gilchrist (1999) and Gertler and Karadi (2011) financial accelerator mechanisms in the model, but we calibrate our model to imply transmission of the three policy tools we consider in line with empirical evidence.

Below is an overview of the model. For any variable X_t, we define its real value as $x_t = X_t/P_t$, where P_t represents the aggregate domestic consumer price level, and x denotes the steady-state value of x_t. Asterisks are used to indicate foreign variables. Additionally, we will sometimes use a bar to differentiate between aggregate quantities that agents take as given and their individual decisions. Naturally, in equilibrium, we have $x_t = \bar{x}_t$.

2.1 Households

We categorize households into two types, "restricted"' and "unrestricted", indexed by $j \in \{r, u\}$, with the proportion of restricted households represented by $\omega_r \in (0,1)$. Each household type j seeks to maximize lifetime utility, expressed as

$$U_t^j = \mathbb{E}_t^j \sum_{s=0}^{\infty} \beta_j^s \, \varepsilon_{t+s}^d \left[\frac{\left(c_{t+s}^j - \varkappa \bar{c}_{t+s-1}^j\right)^{1-\sigma}}{1-\sigma} - \frac{\left(n_{t+s}^j\right)^{1+\varphi}}{1+\varphi} \right], \tag{1}$$

where $\beta_j \in (0,1)$ is the subjective discount factor, $\varphi > 0$ is the inverse Frisch elasticity of labor supply and $\sigma > 0$ denotes relative risk aversion. Household preferences in consumption c_t^j (adjusted for habits that depend on the aggregate consumption of the same type of agents $\bar{c}_t^j$) and labor n_t^j are influenced by the discount factor shock ε_t^d which is modeled as a stationary AR(1) process with unit mean. In the lifetime utility maximand in eq. (1), $\mathbb{E}_t^j$ represents the expected value operator under the subjective expectations of type j households. We allow for deviations from rational expectations by incorporating the approach of Gabaix (2020), assuming that households may exhibit myopia.[8]

The model economy includes two types of nominal assets in the home (H) and the foreign (F) economies respectively: short-term bonds and long-term bonds. The holdings of these assets by agents of type j are denoted as $B_{k,t}^j$ and $B_{k,L,t}^j$ for $k = \{H, F\}$. Following Woodford (2001), we model long-term bonds as perpetuities that pay an exponentially decaying coupon of 1, κ, κ^2,... starting from the period after issuance, where $\kappa \in (0,1]$. By the absence of arbitrage, the current price of a long-term bond issued s periods ago, $P_{L-s,t}$, must be related to the price of a newly issued perpetuity, $P_{L,t}$, by the relation $P_{L-s,t} = \kappa^s P_{L,t}$. A useful consequence of this structure is that we only need to track the price of the long-term bond issued contemporaneously, as the prices of all previous vintages can be easily derived using this formula. This setup also implies that the yield to maturity on long-term bonds, which we refer to as the long-term rate, is given by $R_{L,t} = \kappa + \frac{1}{P_{L,t}}$.

Unrestricted households can trade both short- and long-term domestic bonds and long-term bonds issued by the foreign government but must incur transaction costs, $\zeta_{H,t}$ and $\zeta_{F,t}$, to hold positions in long-term bonds. These considerations result in the following flow budget constraint:

$$P_t(1+\tau_t^c)c_t^u + B_{H,t}^u + \left(1+\zeta_{H,t}\right)P_{L,t}B_{H,L,t}^u + \left(1+\zeta_{F,t}\right)S_t P_{L,t}^* B_{F,L,t}^u + T_t^u = R_{t-1}B_{H,t-1}^u + P_{L,t}R_{L,t}B_{H,L,t-1}^u + S_t P_{L,t}^* R_{L,t}^* B_{F,L,t-1}^u + W_t(1-\tau_t^n)\bar{n}_t^u + D_t^u + \Xi_t^u, \tag{2}$$

[8] More specifically, when anticipating the future, households shrink their expectations toward the economy's steady state. See Kolasa et al. (2025) and Erceg et al. (2024) for a fuller discussion of the specification of how myopia is modeled.

where τ_t^c denotes the value added tax, τ_t^n is the labor income tax, and T_t^u are lump sum taxes. R_t is the short-term policy interest rate and S_t is the nominal exchange rate expressed as the home currency price of one unit of foreign currency. $W_t \bar{n}_t^u$ is pre-tax labor income including net insurance payments insulating households from idiosyncratic income risk (see more details below). Unrestricted households incur transaction costs associated with trading in long-term bonds, specified as follows:

$$\frac{1+\zeta_{k,t}}{1+\zeta_k} = \left(\frac{P_{L,t} b_{k,L,t}^u}{P_L b_{k,L}^u}\right)^{\xi}. \tag{3}$$

These costs are rebated in a lump sum fashion through Ξ_t^u.

In contrast, restricted households trade exclusively in domestic long-term bonds, incurring negligible transaction costs.[9] Consequently, their budget constraint is:

$$P_t(1+\tau_t^c)c_t^r + P_{L,t}B_{H,L,t}^r + T_t^r = P_{L,t}R_{L,t}B_{H,L,t-1}^r + W_t(1-\tau_t^n)\bar{n}_t^r + D_t^r. \tag{4}$$

2.2 Wage Setting

We assume that labor supplied by individual households is differentiated and then pooled by perfectly competitive labor unions using a constant elasticity of substitution (CES) aggregation function, governed by the parameter $\phi_w > 0$. This process yields a standardized labor service provided to firms, represented by the following equation:

$$n_t = \left(\int_0^1 n_t(h)^{\frac{1}{1+\phi_w}} dh\right)^{(1+\phi_w)}, \tag{5}$$

where h indexes individual households. Wages are set by labor unions in a staggered, Calvo-style process. Each period, a random fraction $1-\theta_w$ of households get to reset their nominal wage, while the rest adjust their wages automatically, linking them to the steady-state inflation rate, π. When unions reset wages, they do so on behalf of all households, focusing on overall preferences rather than those of specific household types. This results in the following optimization problem:

$$\max_{\widetilde{W}_t} \mathbb{E}_t^j \sum_{s=0}^{\infty} (\beta\theta_w)^s \left[\Lambda_{t+s} e^{\varepsilon_{t+s}^w} \Pi^s \frac{\widetilde{W}_t}{P_{t+s}} - \frac{e^{\varepsilon_{t+s}^d}}{1+\varphi}\left(\frac{\widetilde{W}_t}{W_{t+s}}\right)^{\frac{\phi_w}{1-\phi_w}\varphi} n_{t+s}^{\varphi}\right]\left(\frac{\widetilde{W}_t}{W_{t+s}}\right)^{\frac{\phi_w}{1-\phi_w}} n_{t+s}, \tag{6}$$

[9] Households in the large (foreign) economy are modeled similarly to those described above, with the exception that restricted agents engage in trading both domestic and foreign long-term bonds.

where $\widetilde{W}_t$ is the newly set wage, Λ_t represents the population-weighted average of the marginal utility of consumption for both restricted and unrestricted households.[10] ε_t^w is a wage cost-push shock that follows a stationary AR(1) process.

2.3 Firms

To introduce price stickiness and imperfect substitution between domestic and imported goods, we consider a three-stage production process. In the final stage, perfectly competitive producers combine homogeneous domestically produced goods $y_{H,t}$ and imported goods $y_{F,t}$ to produce final private and public consumption goods according to the following production technology:

$$c_t = \left(\eta_c^{\frac{1}{\nu}} y_{H,t}^{\frac{\nu-1}{\nu}} + (1-\eta_c)^{\frac{1}{\nu}} y_{F,t}^{\frac{\nu-1}{\nu}}\right)^{\frac{\nu}{\nu-1}}, \quad g_t = \left(\eta_g^{\frac{1}{\nu}} y_{H,t}^{\frac{\nu-1}{\nu}} + \left(1-\eta_g\right)^{\frac{1}{\nu}} y_{F,t}^{\frac{\nu-1}{\nu}}\right)^{\frac{\nu}{\nu-1}} \tag{7}$$

where $\eta_c, \eta_g \in (0,1)$ are the home-bias parameters, indicating the preference for domestic goods, and $\nu > 0$ represents the elasticity of substitution between domestic and imported goods. At the middle production stage, perfectly competitive domestic and foreign firms produce final goods by combining inputs based on

$$\int_0^1 G\left(\frac{y_{k,t}(i)}{y_t}\right) di = 1, \tag{8}$$

for $k = \{H, F\}$. We parameterize the Kimball aggregator $G(x)$ as in Dotsey and King (2005) by assuming

$$G(x) \equiv \frac{\phi}{1+\psi}[(1+\psi)x - \psi]^{\frac{1}{\phi}} - \frac{\phi}{1+\psi} + 1, \tag{9}$$

with $\psi \leq 0$. This specification implies that the steady state markup μ equals $\phi/[(1-\phi)(1+\psi)+\phi]$. Notably, with this specification firms raise prices by a greater amount than they reduce them in response to equivalent percentage changes in marginal costs. This tendency arises from firms' efforts to stabilize their markups. When marginal costs are low, markups are high, giving firms limited incentive to lower prices—especially under quasi-kinked demand conditions, where price cuts yield only minimal increases in demand. One nice property of this specification is that the Dixit–Stiglitz aggregator is a special case when $\psi = 0$.

Intermediate inputs are produced by monopolistically competitive firms, indexed by i, each operating a linear production function based on local labor

$$y_{H,t}(i) + y_{H,t}^*(i) = e^{\varepsilon_t^z} n_t(i) - f, \tag{10}$$

where $y_{H,t}(i)$ and $y_{H,t}^*(i)$ denote the output of an individual firm that is sold domestically and exported, respectively, ε_t^z is a productivity shock (driven by a stationary AR(1) process), $n_t(i)$ is hours worked at a

[10] To simplify the model, we assume the existence of perfect insurance schemes that protect against individual income risks arising from staggered wage setting.

particular firm, and $f > 0$ is a fixed cost of production. Each period, firms face a fixed probability θ_H of reoptimizing their domestic prices, and a probability of θ_H^* of export price reoptimization, while firms that do not reset their prices adjust them according to steady-state inflation. Additionally, we assume that firms' marginal costs are affected by an exogenous stationary AR(1) shock, ε_t^m, which can be interpreted as representing stochastic variations in proportional taxes imposed on firms. These taxes are rebated to the firms in a lump-sum manner.

Assuming that firms do not exhibit myopia and local firm ownership by restricted and unrestricted households is proportional to their shares in the population, the reoptimization problem of firms can be written as

$$\max_{\tilde{P}_{H,t}(i)} \mathbb{E}_t \sum_{s=0}^{\infty} (\theta_H)^s \frac{\Lambda_{t+s}}{P_{t+s}} \left(\tilde{P}_{H,t}(i) \pi^s - e^{\left(\varepsilon_{t+s}^m - e^{\varepsilon_{t+s}^Z}\right)} W_{t+s} \right) y_{H,t+s}(i), \tag{11}$$

$$\max_{\tilde{P}_{H,t}^*(i)} \mathbb{E}_t \sum_{s=0}^{\infty} (\theta_H^*)^s \frac{\Lambda_{t+s}}{P_{t+s}} \left(S_{t+s} \tilde{P}_{H,t}^*(i) \pi^{*,s} - e^{\left(\varepsilon_{t+s}^m - e^{\varepsilon_{t+s}^Z}\right)} W_{t+s} \right) y_{H,t+s}^*(i), \tag{12}$$

where $\tilde{P}_{H,t}(i)$ is the newly adjusted price for the home market and $\tilde{P}_{H,t}^*(i)$ is the price for the foreign market. $\pi_t = P_t / P_{t-1}$ and $\pi_t^* = P_t^* / P_{t-1}^*$ are the domestic and foreign final good inflation rates.

2.4 Fiscal Authority

The fiscal authority operates according to the following nominal flow budget constraint

$$B_t^f + P_{L,t} B_{L,t}^f + \mathcal{T}_t + \Phi_t^c = R_{t-1} B_{t-1}^f + \left(1 + \kappa P_{L,t}\right) B_{L,t-1}^f + P_{G,t} g_t, \tag{13}$$

i.e., it funds its expenditures $P_{G,t} g_t$ (where $P_{G,t}$ is the price of g_t as defined in equation (7)), after accounting for taxation $\mathcal{T}_t$ and profits from the central bank's asset portfolio Φ_t^c, by issuing nominal short-term bonds B_t^f and long-term bonds $B_{L,t}^f$.

Since the government issues bonds with varying maturities, measuring consolidated government debt requires a clear approach to valuing long-term debt. We follow the principle used in government debt statistics, which are based on the face value rather than the market value of debt. Accordingly, we value long-term government debt (perpetuities that pay an exponentially declining coupon of $1, \kappa, \kappa^2$,... starting from the period after issuance, where $\kappa \in (0,1]$) by discounting the outstanding stock of long-term bonds by $1/(1-\kappa)$. This allows us to define the consolidated government debt as a share of annualized trend GDP as

$$GD_t^{con} = \frac{B_t^f + \frac{1}{1-\kappa} B_{L,t}^f}{4 P_t Y}. \tag{14}$$

Our measure of the consolidated fiscal position, GD_t^{con}, is not based on mark-to-market valuation, i.e. as $B_t^f + P_{L,t}B_{L,t}^f$. This means that we exclude direct revaluation effects, and central bank purchases of bonds on the secondary market, which alter the price of outstanding long-term debt, have no immediate impact on GD_t^{con}.[11]

Government consumption g_t is given by $g_t = ge^{\varepsilon_t^g}$ where ε_t^g is assumed to follow an exogenous stationary AR(2) process:

$$\Delta\varepsilon_t^g = \rho_{g,1}\Delta\varepsilon_{t-1}^g - (\rho_{g,2})(\varepsilon_{t-1}^g - 1) + u_{g,t}, \quad u_{g,t} \sim N(0, \sigma_g). \tag{15}$$

where Δ is the first difference operator. We employ an AR(2) process for government consumption for two key reasons. First, to evaluate how inflation responds to a similar output boost, as with unconventional monetary policy, i.e. negative interest rates and large-scale asset purchases. Second, to account for delays in implementing fiscal stimulus. Even though a spending bill may pass in parliament, it takes time to boost the government consumption level.

On the revenue side, total nominal tax revenues ($\mathcal{T}_t$) are made up of two types of components: proportional taxes on consumption and labor income, as well as lump sum taxes, i.e.

$$\mathcal{T}_t = \tau_t^c P_t c_t + \tau_t^n W_t n + T_t. \tag{16}$$

Consumption sales taxes are assumed to be constant ($\tau_t^c = \tau^c$), but labor income taxes vary gradually around its steady state level τ^n to stabilize the consolidated government debt position GD_t^{con} in the long run according to:

$$\tau_t^n - \tau^n = \psi_\tau(\tau_{t-1}^n - \tau^n) + (1 - \psi_\tau)\psi_b(GD_t^{con} - GD^{con}). \tag{17}$$

Setting ψ_τ close to unity and ψ_b small (see Section 2.8) ensures the long-term sustainability of government debt, while allowing for a very gradual and smooth adjustment of labor income taxes. This approach follows the normative analysis presented by Bohn (1990). Another key advantage of this setup is that short- and medium-term debt dynamics are influenced by other endogenous factors (e.g. tax bases), which is our aim. The gradual nature of tax adjustment implies that it does not matter much if consolidated debt in the tax rule (17) is valued at steady state bond prices or mark-to-market.

When analysing the fiscal implications of economic shocks and policy decisions, it is useful to define the fiscal deficit as:

$$D_t^f = (R_{t-1} - 1)B_{t-1}^f + B_{L,t-1}^f + P_t g_t - \mathcal{T}_t - \Phi_t^c. \tag{18}$$

[11] It can be verified that neither the qualitative outcomes nor quantitative long-term effects (e.g., over a 5-year horizon) for GD_t^{con} are notably influenced by reasonable alternative definitions, including those based on mark-to-market valuation.

In this formulation, the deficit consists of debt servicing costs—which include net interest payments on short-term bonds and coupon payments on long-term bonds—and government spending, minus tax revenues and central bank profits. Given that debt is issued in nominal terms, its servicing cost is fixed in nominal terms, which means that unexpected inflation effectively reduces the real cost of debt. Naturally, the fiscal deficit must match the net issuance of debt by the treasury. We can demonstrate this by combining equations (13) and (18) and expressing them in real terms as follows:

$$d_t^f = b_t^f - \frac{b_{t-1}^f}{\pi_t} + P_{L,t}\left(b_{L,t}^f - \kappa \frac{b_{L,t-1}^f}{\pi_t}\right). \tag{19}$$

Recall that our preferred debt measure (as defined in equation 14) is based on its face value. In real terms, and before adjusting by steady-state output, this measure is given by $b_{L,t}^f + b_{L,t}^f/(1+\kappa)$. Equation (19) highlights that a change in this measure of fiscal position is positively influenced by fiscal deficits but negatively impacted by increases in inflation and long-term bond prices. The latter effect reflects the debt deflation channel: as debt is nominal, its real value is diminished by inflation. Additionally, higher bond prices typically contribute negatively to the fiscal position, as they allow the government to issue fewer bonds at a given face value when they can be sold at a higher price.

2.5 Monetary Authority

The monetary authority follows a "conventional" monetary policy using a Taylor-type feedback rule for the gross nominal policy rate R_t, which is constrained by an effective lower bound (ELB), that is both time-varying and slightly negative to account for a negative interest rate policy. This approach represents a significant departure from the analysis in Adrian et al. (2024) and can be formalized as follows:

$$R_t = max\{\lambda_t, \tilde{R}_t\}, \qquad \frac{\tilde{R}_t}{\check{R}_t} = \left(\frac{\tilde{R}_{t-1}}{\check{R}_{t-1}}\right)^{\gamma_r} \left[\left(\frac{\pi_t}{\pi}\right)^{\gamma_\pi} \left(\frac{y_t}{y_{t-1}}\right)^{\gamma_y}\right]^{1-\gamma_r} e^{\varepsilon_t^r}. \tag{20}$$

In this framework, $\tilde{R}_t$ represents the unrestricted (shadow) rate that would apply if the ELB constraint ($\lambda_t \leq 0$) did not exist. Here, $\gamma_r \in (0,1]$ controls the degree of interest rate smoothing, while γ_π and γ_y determine the responsiveness of the policy interest rate to deviations of core CPI inflation (π_t) and output growth (y_t/y_{t-1}) from their steady-state levels, respectively. It is fitting for the central bank to respond to a measure of inflation that includes prices of domestic and imported goods, since both are sticky. As the model incorporates variations in the effective discount factor (as shown in equation (22)), these variations can be neutralized through appropriate adjustments in the short-term policy rate path. The policy rule (20) thus allows for a time-varying neutral gross policy rate $\check{R}_t$, defined as the steady-state nominal gross policy rate adjusted for the expected change in the discount factor shock ε_t^d

$$\check{R}_t = RE_t \frac{\varepsilon_t^d}{\varepsilon_{t+1}^d}, \tag{21}$$

To explore the role of asset purchases when policy rates may be constrained by the ELB for extended periods, we assume that the discount factor shock ε_t^d follows a persistent AR(1) process:

$$\varepsilon_t^d - 1 = \rho_d(\varepsilon_{t-1}^d - 1) + u_{d,t}, \quad u_{d,t} \sim N(0, \sigma_d), \tag{22}$$

This setup enables a gradual and persistent decline in $\breve{R}_t$ below the ELB. Additionally, the policy rule (20) accommodates a standard i.i.d. short-term policy rate shock ε_t^r, which is normally distributed.

The central bank can also participate actively in the domestic bond market by holding a position $B_{L,t}^c$ in long-term bonds, which is entirely funded by issuing one-period reserves that pay interest R_t. From the perspective of private agents, these reserves are equivalent to short-term government bonds. We define domestic asset purchases as $QE_t \equiv P_{L,t}B_{L,t}^c$. We assume that this quantity follows the rule

$$QE_t \equiv \left(1 + (1 - \varrho)\left(\kappa \frac{P_{L,t}}{P_{L,t-1}} - 1\right)\right) QE_{t-1} + \varepsilon_t^{QE}, \tag{23}$$

where $0 < \varrho < 1$ is a parameter governing the reinvestment strategy. Consequently, the central bank's portfolio of purchased domestic assets resembles a standard AR(1) process, with an endogenous component affecting its persistence. As explained in Section 2.8, the coefficients in eq. (23) is set to that a given asset purchase announcement ε_t^{QE} raises QE_t in line with empirical evidence.

Asset purchases are often announced as planned purchase programs, with the total intended amount specified and spread across future periods. For example, Sveriges Riksbank has announced and conducted all of its asset purchases this way since 2015. Following Laséen and Svensson (2011), we model a given announced discretionary asset purchase plan as a sequence of expected innovations in ε_t^{QE} which over time increases QE_t.

We also allow the central bank to conduct sterilized FX interventions. Following Kolasa and Wesolowski (2023), these are modelled as purchases of foreign long-term bonds $F_{L,t}^c$, financed with newly created reserves. As in the case of domestic asset purchases QE_t, we assume that the stock of FX reserves (expressed in domestic currency) $FXI_t \equiv S_t P_{L,t}^* F_{L,t}^c$ evolves according to

$$FXI_t \equiv \left(1 + (1 - \varrho)\left(\kappa^* \frac{P_{L,t}^*}{P_{L,t-1}^*} - 1\right)\right) FXI_{t-1} + \varepsilon_t^{FXI}, \tag{24}$$

where we assume the same reinvestment strategy parameter ϱ as in equation (22).

The central bank's asset portfolio is $P_{L,t}B_{L,t}^c + S_t P_{L,t}^* F_{L,t}^c = -B_t^c$ and any profits or losses made on it are fully backed by the government. The one-period holding profits, Φ_t^c, from previous central bank asset purchases can be expressed as:

$$\Phi_t^c \equiv R_{t-1}B_{t-1}^c + (1 + \kappa P_{L,t})B_{L,t-1}^c + (1 + \kappa^* P_{L,t}^*)S_t F_{L,t-1}^c, \tag{25}$$

The first term on the right side of equation (24) represents the gross cost of financing a given portfolio of long-term assets; without LSAPs and FXIs, B_{t-1}^c would be zero. The second and third terms denote the current market value of the domestic and foreign long-term assets purchased by the central bank up to period $t-1$ (LSAP and FXI, respectively), including the current coupon payment. A positive stock of long-term assets in period $t-1$ implies that B_{t-1}^c is negative. Thus, the combined negative short- and positive long-positions yield a net profit for the central bank. Since these profits are immediately transferred to or financed by the treasury, we regard Φ_t^c as the period-by-period profit. The accumulated profits on the portfolio purchased in period t over the period $t+h$ are therefore given by:

$$CBPROF_{t+h}^{Acc} \equiv \Phi_t^c + \Phi_{t+1}^c + \cdots + \Phi_{t+h}^c. \tag{26}$$

2.6 Market Clearing Conditions

Equilibrium in the goods market requires

$$y_t \equiv y_{H,t}\Delta_{H,t} + \frac{1-\omega}{\omega} y_{H,t}^* \Delta_{H,t}^* = e^{\varepsilon_t^z} n_t - f, \tag{27}$$

where $n_t = \omega_r n_t^r + (1-\omega_r) n_t^u$ is aggregate labor input, y_t defines aggregate output, and

$$\Delta_{H,t} = \frac{1}{1+\psi}\left(\int_0^1 \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{\frac{1}{1-\phi}} di\right)^{-\phi} \int_0^1 \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{\frac{\phi}{1-\phi}} di + \frac{\psi}{1+\psi}, \tag{28}$$

$$\Delta_{H,t}^* = \frac{1}{1+\psi}\left(\int_0^1 \left(\frac{P_{H,t}^*(i)}{P_{H,t}^*}\right)^{\frac{1}{1-\phi}} di\right)^{-\phi} \int_0^1 \left(\frac{P_{H,t}^*(i)}{P_{H,t}^*}\right)^{\frac{\phi}{1-\phi}} di + \frac{\psi}{1+\psi}, \tag{29}$$

represent price dispersion resulting from staggered price-setting in the intermediate goods sector.

In addition, we have market-clearing conditions for bonds issued by the domestic government, including central bank reserves

$$(1-\omega_r) B_{H,t}^u = B_t^f - B_t^c, \tag{30}$$

and

$$\omega_r B_{H,L,t}^r + (1-\omega_r) B_{H,L,t}^u + \frac{1-\omega}{\omega}\omega_r^* B_{H,L,t}^{r,*} + \frac{1-\omega}{\omega}(1-\omega_r^*) B_{H,L,t}^{u,*} = B_{L,t}^f - B_{L,t}^c. \tag{31}$$

Hence, the long term bonds issued by the government $B_{L,t}^f$ are held by either the domestic central bank, $B_{L,t}^c$, or by restricted and unrestricted households at home, $B_{H,L,t}^r$ and $B_{H,L,t}^u$ or in the foreign economy, $B_{H,L,t}^{r,*}$ and $B_{H,L,t}^{u,*}$.

2.8 Model Calibration and Solution

At an overall level, the model is calibrated to match the transmission of short-term monetary policy shocks, the existing evidence on the transmission of government spending shocks in open economies (Sweden in particular), and the effects of LSAP according to academic studies. By aligning the calibration with empirical evidence on policy transmission, we account for Rey's (2015) argument that domestic policy instruments have a smaller impact in small open economies.[12]

Operationally, the model is calibrated following standard practice, beginning with standard parameters that influence steady state of the economy. This part of calibration concerns in particular the parameters governing fiscal flows, followed by those associated with the bond market. The bond market calibration is tailored to reflect Swedish conditions, distinguishing it slightly from the standard international benchmarks. Finally, the parameters related to sticky prices, sticky wages, and habit formation are chosen to ensure realistic transmission mechanisms for interest rate policy and government spending shocks. It is important to note that the parameters used here are largely standard in the literature, apart from the bond market adjustment costs specific to Sweden. Our calibration targets and parameter choices are summarized in Tables 1-3. The time period is one quarter.

Table 1. Targeted Steady State Ratios for Government

Parameter/Expression	Value	Description
$400(\pi - 1)$	2	Core CPI Inflation (annual)
g/y	0.28	Government expenditure-output ratio
$\frac{P_L}{v}\left[\omega_r b^r_{H,L} + (1-\omega_r)\left(b^u_{H,L} + b^u_{F,L}\right) - b^f_{H,L}\right]$	0	Net Foreign Assets to GDP
$P_L b^f_L / (b^f + P_L b^f_L)$	0.8	Long term bonds to total bonds
$b^c_L, \quad f^c_L, \quad b^c_{\square}$	0	Central bank portfolio
$\left[\omega_r b^r_{H,L} + (1-\omega_r) b^u_{H,L}\right] / b^f_L$	0.65	Home long-term bonds held by residents

Following Kolasa and Wesolowski (2020) and Akkaya et al. (2023a,b), we model the large foreign economy as a bloc consisting of three key economies: the United States, the euro area, and the United Kingdom (referred to as BIG3). Hence, our calibration of the large foreign economy's parameters closely follows their methodologies, given the shared definition of this economic bloc. These countries make up for the bulk of Sweden's trade and financial linkages, and Sweden represents the small domestic open economy in our

[12] Following Rey (2015), foreign shocks – including fiscal and monetary policies – can matter more for business cycles in small open economies than domestic shocks. But it does not follow from this evidence that domestic policy is toothless, and Rey's insight can be considered by setting parameters in the structural model to match the empirical evidence of domestic policy instruments.

framework with its relative size quantified by the parameter $\omega = 0.015$. This value is derived from Sweden's nominal GDP as a fraction of the BIG3's nominal GDP over the period 1995–2019.

The steady state inflation rate is calibrated to the Riksbank's inflation target of 2 percent which implies the gross quarterly inflation rate $\pi = 1.005$. The discount rates of restricted and unrestricted households are calibrated to $\beta_r = 0.99813$ and $\beta_u = 0.99875$. These calibrations imply steady state short- and long-term interest rates of 2.5 percent and 2.75 percent respectively. This calibration is chosen to match measures of the term premium of a 5-year government bond in Sweden of around 25 basis points on average. We choose to calibrate these parameters symmetrically for the large economy. The home bias parameter for private consumption η_c and that for public consumption η_g are calibrated at 0.7 and 0.95, respectively, to capture the average share of imports in the Swedish GDP and account for the relatively low import content of government purchases. The elasticity of substitution between domestically produced goods and imports is set to 1.3. The elasticity of intertemporal substitution is calibrated as $\sigma = 2$. The inverse Frisch elasticity is calibrated to $\varphi = 4$, which is broadly in line with the foreign economy and Swedish economy estimates in Corbo and Strid (2020). The (steady state) government expenditure-output ratio, the labor-income tax and the consumption tax are all set equal to their sample means. This implies $g/y = 0.28$, $\tau_y = 0.24$, $\tau_c = 0.17$, respectively.

A key aspect of our calibration focuses on the structure of the bond market. Here we rely mostly on the careful calibration conducted by Akkaya et al. (2023a,b). The steady-state ratio of sovereign bonds to annual GDP is set at 1.4 (4 × 0.35), reflecting both the Swedish government's Maastricht debt target and data from the period 2002–2019. We assume that central bank holdings of domestic and foreign government bonds are initially zero. The share of long-term bonds in total sovereign bond issuance by the home economy is calibrated at 0.8, with their average duration set at six years. The average duration of foreign long-term bonds is assumed to be 7.5 years. The steady-state share of resident holdings in the small economy's total issuance of long-term bonds is calibrated at 0.65. Additionally, we assume that restricted and unrestricted households exhibit the same degree of home bias in their portfolios of long-term bonds. Given that balanced trade implies zero net foreign assets, these assumptions collectively determine the steady-state distribution of bond holdings across agent types in both economies.

Table 2. Calibration of Parameters Pertaining to Households and Firms

Parameter	Value	Description
	Households	
ω	0.015	Size of the small economy
ω_r	0.1	Share of restricted households
σ	1	Inv. elasticity of intertemporal substitution
φ	2	Inv. Frisch elasticity of labor supply
β_u	0.99875	Discount factor, unrestricted households
β_r	0.99813	Discount factor, restricted households

m_u	0.95	Cognitive discounting, unrestricted households
m_r	1	Cognitive discounting, restricted households
ϕ_w	1.5	Wage markup
θ_w	0.75	Calvo wage probability
ξ	0.025	Transaction cost on long-term bonds
Firms		
v	1.3	Elasticity of substitution btw. domestic production and imports
η_c	0.7	Home bias in private consumption
η_g	0.95	Home bias in public consumption
μ	1.15	Gross price markup
ψ_H	-12	Kimball parameter for domestic producers
ψ_F	-6.5	Kimball parameter for imports
θ_H,θ_F	0.667	Calvo probability for domestic production and imports

Notes: μ is a composite parameter defined as $\mu = \phi/[(1-\phi)(1+\psi)+\phi]$.

Another important group of parameters determine the degree of market segmentation and sensitivity of transaction costs, and hence the term premia, to adjustments in agents' portfolios. Two key parameters influence the effects of central bank asset purchases on the economy: the share of restricted households and the sensitivity of unrestricted households' bond transaction costs to the share of government debt securities in their portfolios. The share of restricted households (ω_r) is calibrated following Kolasa and Wesolowski (2020) to 0.1. The transaction cost parameter (ξ) is calibrated to ensure that the effects of asset purchases on bond term premia align with empirical evidence on LSAPs announcement effects and is set to 0.025. This choice is based on achieving a max peak in output after a one percent increase in asset purchases which is materially lower than the mean peak effects found by non-central bank research papers as was reported by Fabo et al. (2021).

We set parameters related to the model's dynamics to align with the evidence on how short-term interest rates, asset purchases, and government spending influence the Swedish economy. For this, we examine changes in policy tools driven by shocks to the short-term interest rate (ε_t^r in Equation 20), central bank asset purchases (ε_t^{QE} in Equation 23), and government consumption ($u_{g,t}$ in Equation 15). These responses are shown in Figure 2. We analyze a 25 basis point cut in the policy rate, a 1 percent of baseline GDP increase in LSAPs (to facilitate comparison with the evidence in Fabo et al. (2021)), and an increase in government spending calibrated to deliver an output boost equivalent to that of the short-term policy rate cut.[13]

[13] Fabo et al. results for LSAPs are based on studies for large, relatively closed economies, whereas our analysis focuses on a small open economy. The studies covered by Fabo et al. also include episodes with financial stress. For these two reasons, we calibrate our effects of LSAPs on output toward the lower range of the academic studies in Fabo et al. Even so, the exchange-rate channel in our analysis implies a higher elasticity between output and inflation compared to Fabo et al., so prices move a bit more relative to output as a weaker exchange rate amplifies the transmission of LSAP.

Table 3. Calibration of Policy Parameters.

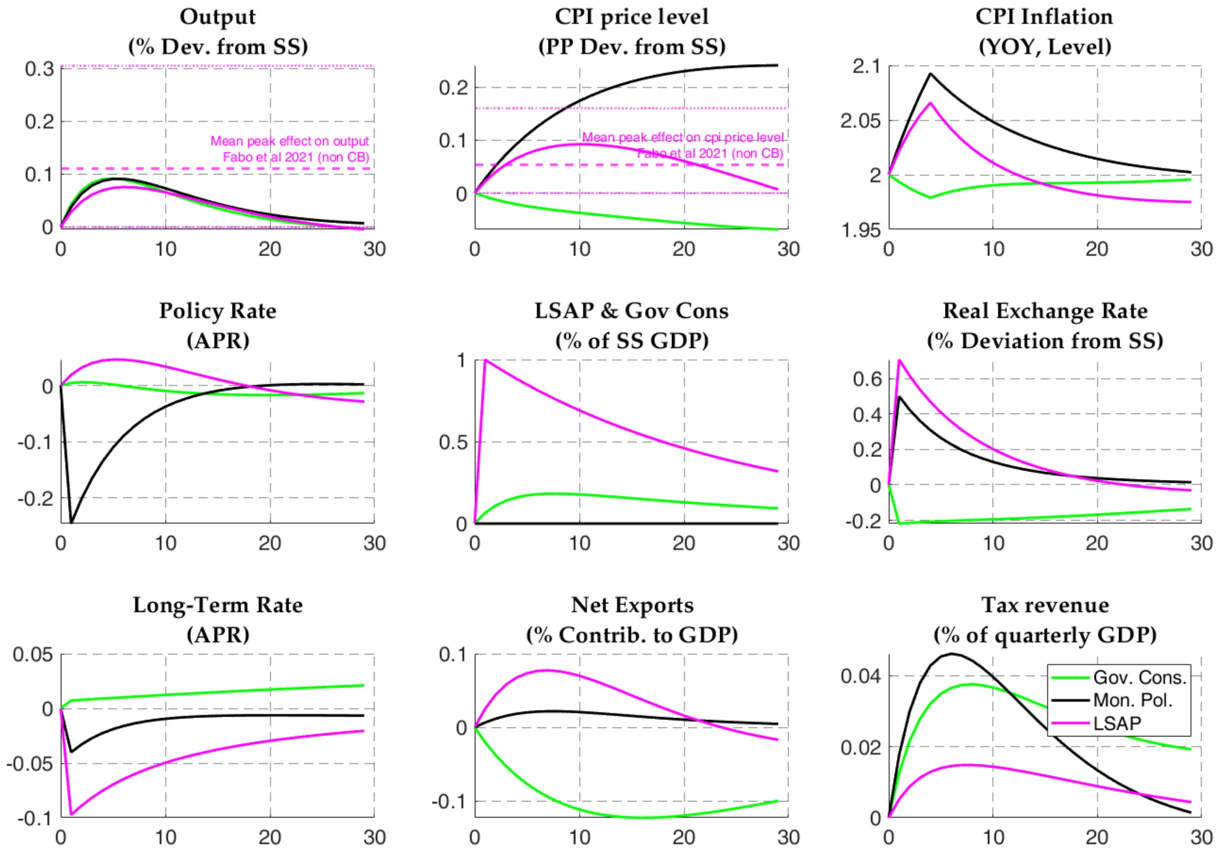
Parameter	Value	Description
	Fiscal	
τ^c	0.2	Steady state consumption value added tax
τ^n	0.3	Steady state labor income tax
g/y	0.28	Government expenditure-output ratio
$(b^f + P_L b_L^f)/y$	1.4	Share of government debt in quarterly GDP
ψ_τ	0.98	Tax Smoothing Coeff in eq. (17)
ψ_b	0.01	Gov.t Debt Response Coeff in eq. (17)
$\rho_{g,1}$	0.70	First difference coeff in eq. (15)
$\rho_{g,2}$	0.01	Error correction coeff in eq. (15)
D	24	Long-term bond duration (domestic)
D^*	30	Long-term bond duration (foreign)
	Monetary	
γ	0.9	Interest rate smoothing
γ_π	1.5	Interest rate response to inflation
γ_y	0.5	Interest rate response to output growth
ϱ	0	Reinvestment strategy

Notes: D is a composite parameter defined as $D = \pi\beta_r^{-1}/(\pi\beta_r^{-1} - \kappa)$.

A key focus of our calibration is the set of parameters governing inflation dynamics, particularly their responses to monetary policy actions. To incorporate a modest degree of cognitive myopia, we set the discounting parameter for unrestricted households to 0.95. Compared to estimates of this parameter within DSGE models (e.g., Gust et al., 2022; Kolasa et al., 2025), our choice implies only a minor departure from rational expectations. To capture state-dependent variations in the slope of the Phillips curve, we follow Harding et al. (2022) and set the Kimball curvature parameter to -12 for domestic firms but -6.5 for export firms. Additionally, the Calvo probabilities are set to 0.667, consistent with empirical evidence on average price durations. This implies log-linearized slopes of the Phillips curves of 0.02 and 0.01, respectively, as specified in Equation (16) of Harding et al. (2022), and with standard Dixit-Stiglitz aggregator (i.e. assuming ψ is set to zero) these log-linearized slopes can be replicated with Calvo parameters of 0.905 and 0.87. Notably, these Calvo parameters are closely aligned with the estimates provided by Corbo and Strid (2020) based on Swedish data. The parameters governing the monetary policy reaction function are calibrated to standard values, consistent with estimates from Corbo and Strid (2020). Specifically, the coefficient on inflation is set to $\gamma_\pi = 1.5$, the coefficient on output growth to $\gamma_y = 0.5$, and the interest rate smoothing parameter to $\gamma_r = 0.9$. We work with output growth instead of output as deviation from trend in the policy rule so that the central bank does not lean much against the output expansion that follows from fiscal stimulus. We adopt a symmetric calibration of these parameters for the large economy.

Our calibrated model indicates that a 0.25 percentage point reduction in the policy rate increases output and inflation by approximately 0.1 percent. These outcomes align with average VAR and DSGE evidence for Sweden and comparable economies, as well as for the euro area and the United States. Table 1 in Appendix 2 provides an extensive review of relevant papers.

Figure 2. Impulse Responses to Government Spending, Policy Rate and Large Scale Asset purchase Shocks.



Notes: This figure compares the impulse response functions (IRFs) for LSAPs worth 1 percent of baseline GDP (magenta line), a short-term interest rate cut by 25 basis points (black line) and an increase in government consumption sized to give a similar output boost as the short-term interest rate policy (green line). The horizontal dashed lines represent the mean, maximum, and minimum peak effects of LSAPs on output and the price level as reported by Fabo et al. (2021) for non-central bank researchers.

In comparison, LSAPs have a slightly smaller effect on output, despite causing a more persistent decline in long-term nominal interest rates. Long-term rates decrease by about 0.1 percentage points (not shown), aligning with the summary results of event studies on Swedish data reported by Andersson et al. (2022) and Christensen and Zhang (2024). The effects on the price level are similarly modest but remain consistent with estimates provided by Fabo et al. (2021) and Christensen and Zhang (2024).

Regarding the effects on fiscal variables, it is worth noting that the budget elasticity, or revenue elasticity—defined as the responsiveness of government revenues to changes in economic activity—is consistent with typical Swedish estimates of approximately 0.5 (Almenberg and Sigonius, 2022). This implies that tax revenues rise by about half of the increase in output. The fiscal multiplier, defined as the change in output divided by the change in government spending as share of output over the first 1 (2) years, is approximately

0.72 (0.67) assuming that spending follows an AR(2) process to match the output propagation of a short-term interest policy shock in Figure 2. This is towards the lower end of Swedish estimates, but under the assumption that government spending follows an AR(1) process – which we will adopt in Section 4.3 – our model implies a higher spending multiplier (0.85 and 0.77 over first and two years, respectively) which is well in line empirical evidence. Even so, the estimates are associated with considerable uncertainty, and our multiplier of about 0.8 falls well within their range.[14] According to the NIER (2021), the two-year multiplier for targeted transfers is close to those for government consumption (0.44 in a normal situation and 0.98 with monetary accommodation at the ELB). Hence, while targeted transfers may create more VAT tax revenues and be less costly from a budgetary perspective than higher government consumption, they will still not be a fiscal free lunch.

Additionally, an increase in asset purchases equivalent to 1 percent of GDP - which then runs off according to the maturity structure of the bonds - results in a 0.65 percent depreciation of the exchange rate. This estimate aligns with recent research demonstrating that central banks' large-scale purchases of domestic long-term bonds significantly influenced foreign exchange rates in addition to long-term bond yields, highlighting important linkages between these markets. For instance, studies by Bauer and Neely (2014), Neely (2015), Glick and Leduc (2018), Swanson (2021), Dedola et al. (2021), Bhattarai and Neely (2022) and Christensen and Zhang (2024) reveal that the Federal Reserve's and Sveriges Riksbank's bond purchases were strongly associated with a substantial depreciation of the U.S. dollar and the Swedish Krona against other major currencies. Greenwood et al. (2023) further contributes to the understanding on the FX effects of LSAPs by developing a model where the limited risk-bearing capacity of global bond market investors plays a central role in determining exchange rates. Importantly, their findings suggest that LSAP policies significantly affect foreign exchange risk premiums and bond term premiums even when interest rates are constrained by the zero lower bound.

To corroborate the findings in Figure 2, Appendix 4 provides empirical evidence on the impact of asset purchase announcements on the exchange rate using a structural vector autoregression (SVAR) model identified with an external instrument. The results reinforce the conclusion that large-scale asset purchases contribute to a significant depreciation of the exchange rate. Specifically, the estimated SVAR implies that an LSAP shock leads to a persistent depreciation of the real exchange rate. The findings are robust and significant when constructing confidence sets for the impulse responses that address concerns about weak instrument bias. Notably, the estimated exchange rate response to LSAPs in our SVAR model supports the effects in our DSGE

[14] Recent studies based on Swedish data examine the effects of fiscal policy on GDP. The Swedish NIER (2021), building on Hjelm and Stockhammar (2016), analyzes fiscal policy measures and macroeconomic variables in Sweden from 1980 to 2015. The focus is on the period with a floating exchange rate (1993 onward), estimating fiscal policy multipliers. Public consumption and public investment emerge as the most impactful measures, with multipliers above 1—indicating that GDP increases by more than the initial spending. However, these estimates are generally not statistically significant, underscoring their uncertainty. Notably, our finding that inflation falls in response to fiscal policy is well in line with Akkaya et al. (2024), who identify this as an empirical result in their estimated DSGE model based on Swedish data, as a fiscal expansion appreciates the exchange rate and lower core CPI inflation via lower prices on imported goods.

model, lending additional credibility to the identified transmission mechanisms. Furthermore, the estimated SVAR implies that an asset purchase shock also leads to an increase in the Riksbank's government bond holdings. In fact, the SVAR results suggest that LSAP shock have a somewhat more sustained impact on the central banks' balance sheet than what we embed into the model, implying that systematic QT happens somewhat faster in the DSGE than suggested by the SVAR.

The response of the exchange rate is also key for the transmission of fiscal policy. As seen from the upper right panel of Figure 2, core CPI inflation falls when government spending on domestic goods increase. This is counter to conventional findings with closed economy structural models. In Section 3, we will explore in greater detail that this seemingly surprising result is primarily driven by exchange rate appreciation accompanying higher fiscal spending; when we assume the small economy is isolated from international trade (i.e. impose trade autarky so exchange rate movements become irrelevant), inflation increases in response to higher government consumption.

To preserve the nonlinearities inherent in the Kimball aggregator and the effective lower bound constraint, we solve the model nonlinearly. However, dealing with behavioral discounting, which is not tractable in a fully nonlinear framework, requires a different approach. Specifically, we first derive the linearized first-order conditions governing the decisions of behavioral agents. In an open economy context, these conditions lead to aggregate Euler equations where the forward-looking components are scaled by the cognitive discounting parameter, m, with an additional additive term that depends on agents' asset holdings. As noted by Kolasa, Ravgotra, and Zabczyk (2025), this term is quantitatively very small. Based on these insights, we approximate the relevant first-order conditions in the nonlinear model using formulas that, when linearized, yield equations consistent with the linear derivations, aside from the aforementioned minor term. We solve the resulting model using the extended path method of Fair and Taylor (1983), which is readily implemented in Dynare (Adjemian et al., 2024). The nonlinear solution technique means that we exploit convexities in the Phillips curves, i.e. a lower sensitivity of inflation to various shocks when there is slack in the economy and inflation is below the central bank's target (see Harding et al. 2022, 2023). This implies that our inflation impact of the alternative policies we consider in the case study in Section 4 is conservative and would be notably larger for the analyzed UMP tools if we linearized the model (apart from the ELB on the short-term policy rate) instead of solving it nonlinearly.

3. Transmission of Asset Purchases, Conventional Interest Rates and Fiscal Policy: The Role of Open Economy Dynamics

In this section, we use the calibrated model to study the role of the exchange rate and openness of the home economy in the transmission of various policy tools. As noted earlier, the three policy tools we study are long-term asset purchases, short-interest rate cuts and higher government spending. We consider a policy rate cut of 25 basis points and an LSAP worth one percent of baseline GDP (to be able to compare with the Fabo et al. (2021) evidence) and size the hike in government spending to provide a commensurate boost to output as the policy rate cut.

In our model, the macroeconomic impact of asset purchases through LSAPs hinges on their effect on the term structure of interest rates and the exchange rate. To better understand this, we examine a linearized arbitrage equation derived by solving the portfolio choice problem of unrestricted households, which relates the expected one-period holding return on long-term bonds ($R^1_{L,t+1} \equiv R_{L,t+1}P_{L,t+1}/P_{L,t}$) to the risk-free interest rate (R_t):

$$\mathbb{E}^u_t \hat{R}^1_{L,t+1} = \hat{R}_t + \zeta_h \hat{B}^c_{h,L,t}, \tag{32}$$

where hats indicate log deviations from the steady state. Here, the last term represents transaction costs, which create a gap between the returns on short- and long-term bonds, and hence determine the term premium. These transaction costs increase with the amount of long-term bonds held by unrestricted agents, who are able to trade both short- and long-term assets. Consequently, when the central bank buys long-term bonds, it reduces the supply of these bonds available to private agents, thereby lowering the expected return on them.

Since unrestricted agents have access to short-term bonds, their consumption decisions can still be described by a standard linearized Euler equation

$$\hat{\Lambda}^u_t = \mathbb{E}^u_t \hat{\Lambda}^u_{t+1} + \hat{R}_t - \mathbb{E}^u_t \hat{\pi}_{t+1}, \tag{33}$$

where $\Lambda^j_t = \varepsilon^d_t/(c^j_t - \varkappa \bar{c}^j_{t-1})$ denotes marginal utility of consumption for agent of type $j \in \{r, u\}$. This equation implies that, unless the path of short-term real interest rate changes, the intertemporal choices of unrestricted agents remain unaffected by shifts in term premiums. In contrast, restricted agents—those who trade only long-term assets—are directly affected by changes in bond prices as their consumption evolves according to the following Euler condition

$$\hat{\Lambda}^r_t = \mathbb{E}^r_t \hat{\Lambda}^r_{t+1} + \mathbb{E}^r_t \hat{R}^1_{L,t+1} - \mathbb{E}^r_t \hat{\pi}_{t+1}. \tag{34}$$

Since, as explained above, LSAPs lower the expected rate of return on long-term bonds, restricted households experience a rise in consumption. Overall, the effect of LSAPs on domestic demand thus depends on the proportion of this type of agents in the economy.

A second key equilibrium condition in our model, particularly significant for international monetary policy interactions, involves portfolio decisions made by foreign agents. This is captured by the following linearized "long" Uncovered Interest Parity (long-UIP) condition:

$$\mathbb{E}_t^u \hat{R}_{L,t+1}^1 = \mathbb{E}_t^u \hat{R}_{L,t+1}^{1,*} + \mathbb{E}_t^u \Delta S_{t+1}, \tag{35}$$

where S_t represents the nominal exchange rate.[15] This equation implies that the expected one-period holding returns on long-term bonds, whether denominated in domestic or foreign currency, must balance. Note that, due to the presence of transaction costs, the standard (short-term rate based) UIP condition does not hold in our model, only the one associated with long-term bonds does. This can be seen by combining equation (35) with equation (32) and its foreign counterpart.

The long-UIP condition implies that, if LSAPs by a central bank decrease the expected return on domestic long-term bonds, and the expected return on foreign bonds remains unchanged reflecting the small open economy assumption, the domestic currency must be expected to appreciate in the next period. Therefore, LSAPs tends to depreciate the implementing country's exchange rate on impact, and persistently so if asset purchases are not expected to be quickly reversed.[16] More generally, equation (35) also implies that domestic bond and FX markets are strongly connected – the exchange rate can only move if long-term yields move and vice versa. This connection does not depend on which shock or policy is driving the adjustment in these variables. As we discuss later, this feature of our model will make LSAPs look similarly to FX interventions. It has to be stressed that the similarity between these two policies is conditional on the absence of FX market-specific frictions a la Gabaix and Maggiori (2015).[17] For example, Gourinchas, Ray and Vayanos (2025) present a model in which the bond and FX markets are disconnected, and hence the long-UIP condition does not hold.

It needs to be stressed that the exchange rate channel of LSAPs described above operates irrespectively of the share of restricted agents in the economy. In other words, even if $\omega_r = 0$ so that term premiums are irrelevant for how households decide to smooth their consumption over time, the exchange rate reaction to asset purchases by the central bank can still significantly affect economic activity and inflation, and hence household income and consumption. This is an important insight given that the direct effect of LSAP can be questioned

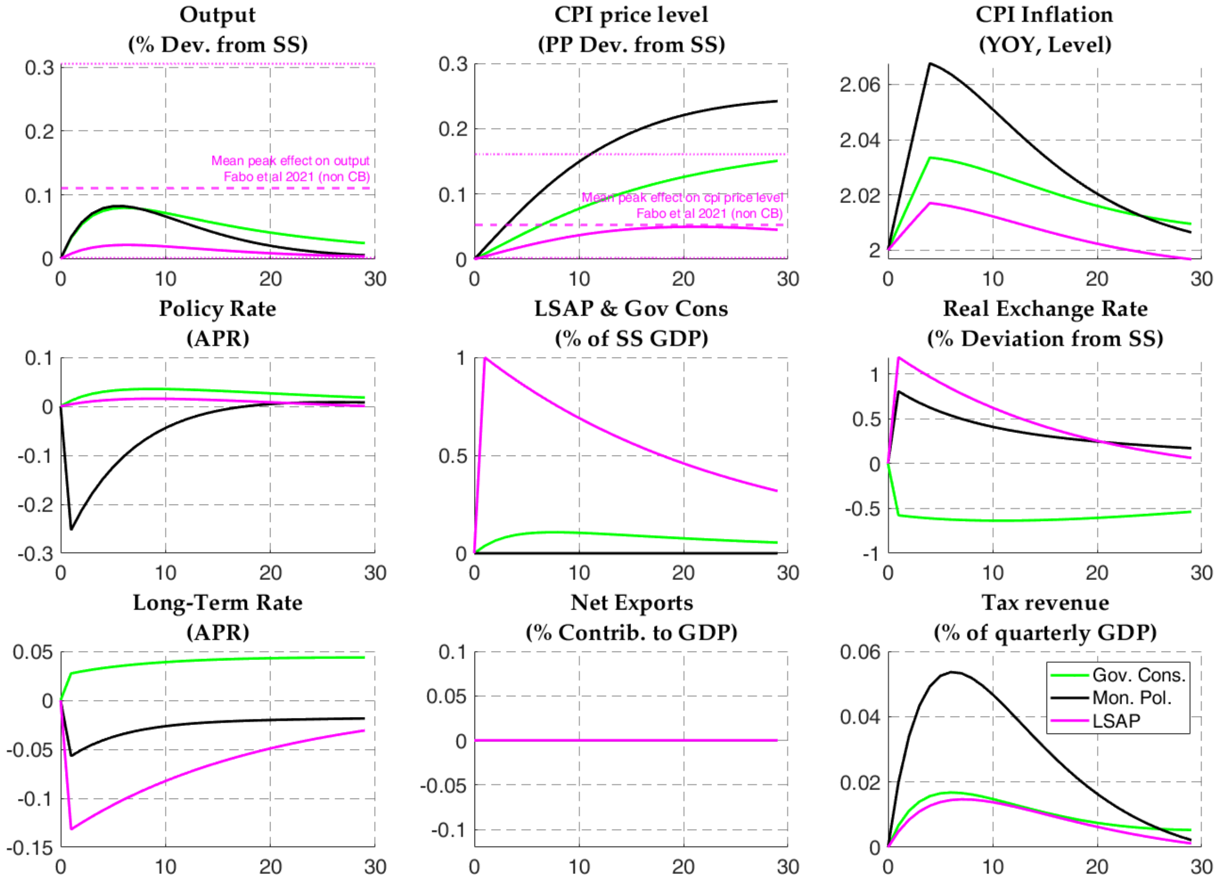
[15] As shown by Lustig et al. (2019), this relationship is likely to hold in the data for advanced economies if bonds with long (10-year) maturity are used. See also Chinn and Meredith (2005) for a related variant of a long-run UIP condition that compares foreign and domestic long-term rates to long-term changes in exchange rates. These findings can be contrasted with the widely documented failure of the standard UIP condition that relies on short-term rates, and which also fails in our model (see Kolasa and Wesołowski, 2020).

[16] Notably, if we assumed that the "long" UIP in equation (32) does not hold exactly but also includes a risk premium, the LSAP transmission to the exchange rate could be weaker, but only if this premium endogenously decreased in reaction to LSAP.

[17] Adrian et al. (2021) show that FX market depth can materially affect how FX interventions propagate quantitatively to output and inflation.

in economies where most agents take variable interest rate loans and are hence only directly influenced by LSAPs to the extent that they signal that short-term rates will remain low for longer.

Figure 3. Impulses to Government Spending, Policy Rate, and a LSAP Shocks Under Trade Autarky.



Notes: This figure compares the impulse response functions (IRFs) for LSAPs with 1 percent of baseline GDP (magenta line), a short-term interest rate cut with 25 basis points (black line) and an increase in government consumption sized to give a similar output boost as the short-term interest rate policy (green line). The horizontal dashed lines represent the mean, maximum, and minimum peak effects of LSAPs on output and the price level as reported by Fabo et al. (2021) by non-central bank researchers. Exports and Imports are shut down by setting the home-bias parameter $\eta_c = \eta_g = 1$ and the elasticity of substitution across consumption goods to infinity ($\nu = \infty$).

To highlight the importance of the transmission channels described above, Figure 3 plots the effects when we simulate a closed economy within our model, showing that the results then align exactly with those of Fabo et al. summary of closed economy effects of LSAPs.[18] This underscores the importance of accounting for openness and exchange rate dynamics in assessing the transmission and effectiveness of LSAPs in small open economies. Furthermore, the effects of LSAPs on output and inflation in our model are driven almost entirely by the open economy aspects, specifically the exchange rate adjustment implied by asset purchases.

[18] To get a closed-economy (trade autarky) version of the model, we follow Adolfson et al (2008b) by establishing that the consumption basket only consists of domestically produced goods. That is, we set the share of imports in consumption to zero ($\eta_c = \eta_g = 1$) and the elasticity of substitution across consumption goods to infinity ($\nu = \infty$).

The importance of open economy dynamics is also evident in the transmission of fiscal policy. An increase in government consumption leads to a decline in CPI inflation in our open economy model, contrasting with the closed (trade autarky) economy model formulation in which inflation rises. This divergence reflects the influence of exchange rate adjustments: in the open economy, the fiscal expansion strengthens the domestic currency, which reduces import prices and dampens inflationary pressures. By contrast, in a closed (trade autarky) economy, the inflationary impact of increased domestic demand dominates due to the absence of external trade and exchange rate effects. These differences highlight the critical role of openness in shaping the macroeconomic outcomes of both monetary and fiscal policies.

Recent empirical research has provided mixed evidence concerning the relation between fiscal shocks and the real exchange rate.[19] Born et al. (2013) obtain significant appreciation for floating regimes. Ferrara et al. (2021) and Forni and Gambetti (2016) also find appreciation under specific conditions, including anticipated shocks or targeted sample periods. Earlier research using European data (Beetsma and Giuliodori 2011; Bénétrix and Lane 2013) similarly associates government spending with real exchange rate appreciation. Crucially, Born et al. (2024) identify a "depreciation bias" in empirical studies, which underestimate appreciation from positive spending shocks and overstate depreciation from negative ones. Correcting for this bias reveals that unexpected government spending appreciably strengthens the real exchange rate in flexible exchange rate regimes like the one we study in this paper.[20]

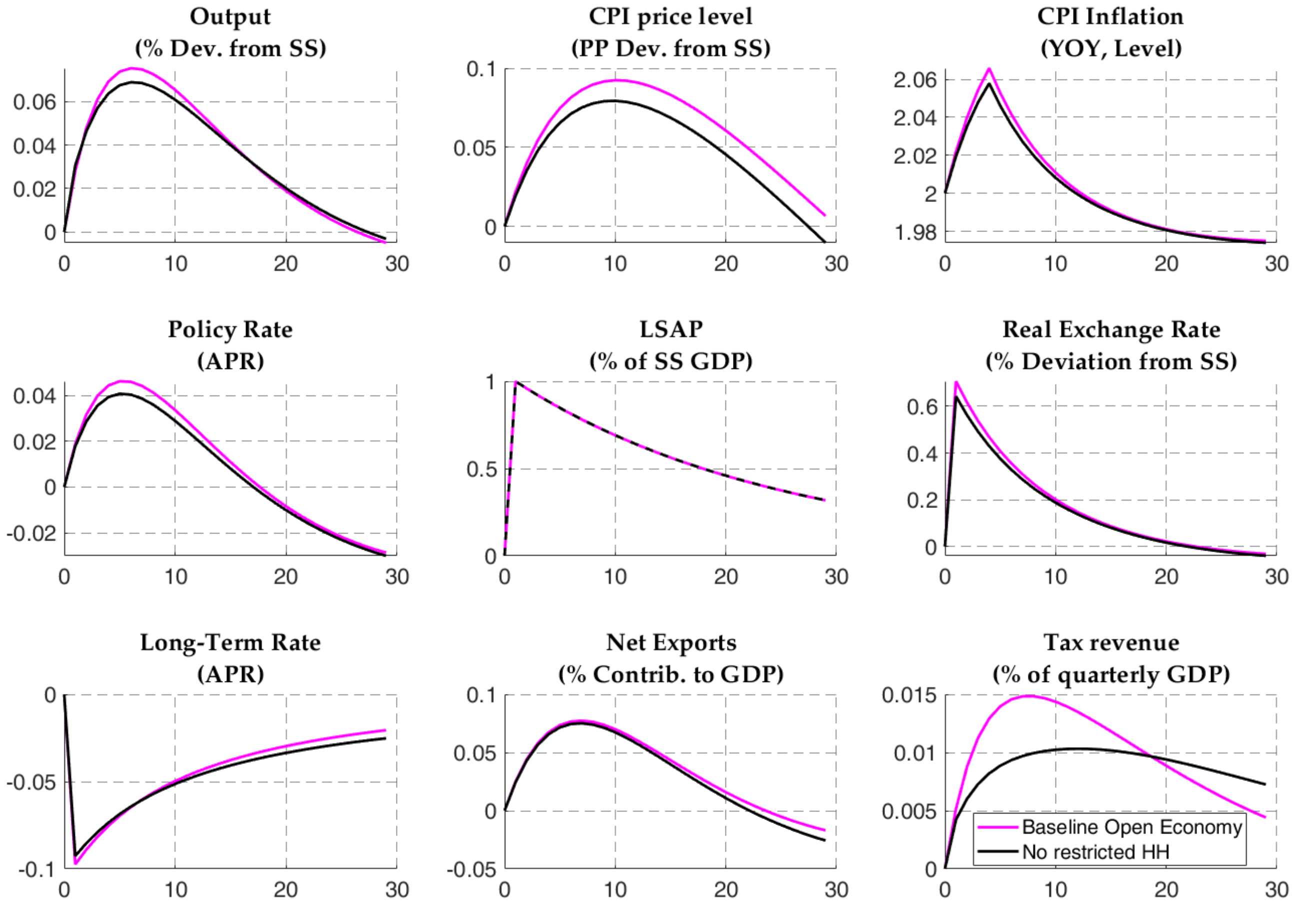
Another way to isolate the exchange rate channel in the model, beyond simulating a closed (trade autarky) economy, is to remove the direct impact of lower long-term interest rates and term premiums on intertemporal choices made by households. The goal is to demonstrate that our results do not hinge on these factors for LSAPs to influence the economy. Hence, this way of isolating the effects speaks to the point made by Flodén (2022) and the Swedish National Audit Office (2023) about the potentially limited inflationary effects of LSAPs in economies where borrowing is mainly short-term or at a variable rate. In our framework, only restricted agents are sensitive to long-term yields as they cannot trade in short-term bonds, while unrestricted agents can arbitrage between short-term and long-term rates. As discussed above, by setting the share of restricted households to zero ($\omega_r = 0$), long-term yields no longer directly affect how households smooth their consumption over time. Under this configuration, LSAPs exert influence on the economy almost exclusively through the "long" Uncovered Interest Parity" (long-UIP) condition, which means that the exchange rate

[19] From a theoretical standpoint, the relationship between fiscal shocks and the real exchange rate is subject to competing predictions across models. Traditional and modern open-economy macroeconomic frameworks with nominal rigidities generally predict that an increase in government spending leads to real exchange rate appreciation (e.g., Corsetti and Pesenti 2001). Conversely, alternative models demonstrate scenarios where fiscal expansion results in real depreciation, as illustrated by Kollman (2010), Monacelli and Perotti (2010), and Ravn, Schmitt-Grohé, and Uribe (2012).

[20] The bias identified by Born et al. (2024) may explain why a several papers find empirically that unexpected increases in government spending depreciate the real exchange rate (e.g., Kim and Roubini 2008; Monacelli and Perotti 2010; Enders et al. 2011; Ravn et al. 2012; Corsetti et al. 2012; Ilzetzki et al. 2013; Forni and Gambetti 2016; Miyamoto et al. 2019).

dynamics becomes the sole transmission channel of domestic LSAP.[21] Indeed, in a closed economy version of our model this policy would not have any effects if the share of restricted households is set to zero. Hence, we can decompose the effects of LSAP on the home economy also by setting $\omega_r = 0$.

Figure 4. Propagation of LSAPs in Baseline Open Economy vs. a Variant Without Restricted Households.



Notes: Figure shows impulse response functions (IRFs) for LSAP with a 1 percent of baseline GDP in baseline open economy model in Figure 2 and in the version of the model without restricted households (ω_r=0).

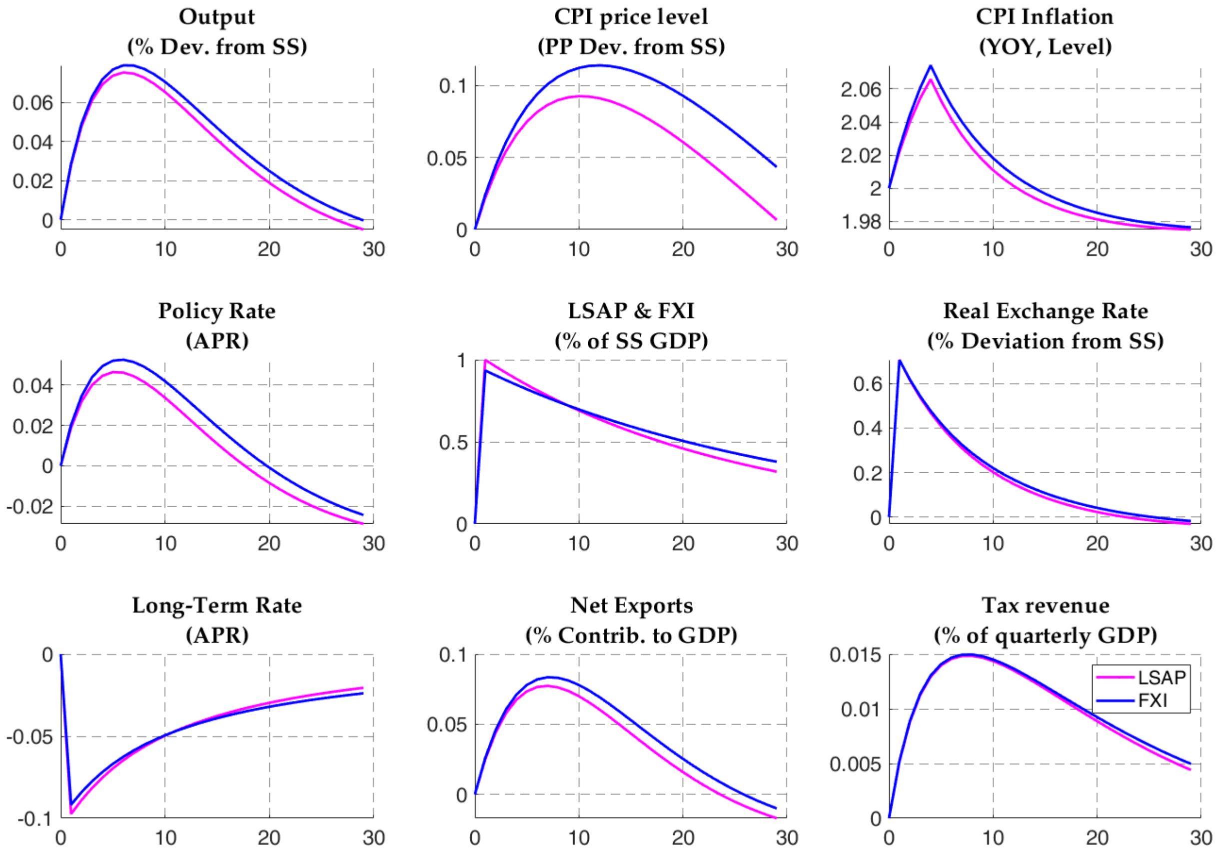
With this in mind, Figure 4 compares IRFs exclusively for LSAPs. As in the previous figures, we analyse a 1 percent of baseline GDP increase in LSAPs for two different model specifications which highlight the open economy aspects of the transmission of LSAPs. The magenta-coloured line simply restates the baseline LSAP impulses in Figure 2, whereas the black line shows the corresponding impulses when ω_r, i.e. the share of households that are directly impacted by long-term yields, is set to nil. As shown by the figure, the results when $\omega_r = 0$ closely resemble the baseline results in Figure 2 where ω_r is greater than zero, confirming that the exchange rate channel remains the primary driver of LSAP effects in our model. This finding underscores the importance of exchange rate adjustment and net export as the key mechanism for LSAPs in our calibrated

[21] To be precise, while long-term bond prices are irrelevant for the time profile of unrestricted agents' consumption (as it is entirely pinned down by the path of short-term rates), they can still affect its level via balance sheet effects. In our model, we allow for cross-border holdings of long-term bonds, which means that LSAP by the home economy generates wealth transfers between domestic and foreign agents, even if the share of restricted households ω_r is zero. However, this channel is not quantitatively big, which we confirmed by rerunning our simulations under the assumption that steady state holdings of foreign bonds are close to zero, finding only small differences.

small open economy model. The path of long-term yields is irrelevant apart from triggering a weakening of the nominal and real exchange rate which stimulates net export. Quantitatively, the elasticity between the REER and NX in Figure 4 is very similar to empirical evidence on this relationship for Sweden that we provide in Appendix 3. Of course, had we calibrated a larger share of restricted households in the baseline model, we would have obtained a larger difference between the magenta and black lines in Figure 4. But even with a notably higher share of restricted households, the exchange rate channel remains key in the open economy.

The reasoning above suggests that the total impact of LSAP in an open economy can be thought of as a direct interest rate channel plus an indirect channel operating mainly/exclusively via a weaking of the exchange rate.

Figure 5. Propagation of LSAPs and FX interventions in the Baseline Open Economy.



Notes: This figure compares the impulse response functions (IRFs) for LSAPs with 1 percent of baseline GDP (magenta line) with an FX intervention sized to give a similar real exchange rate path (blue line).

To quantify this statement, Figure 5 compares the impact of an FX intervention that weakens the exchange rate with LSAP in the baseline open economy model. As before, LSAPs are modelled as CB purchases of domestic long-term bonds financed by CB reserves. Now, FX intervention is modelled as CB purchases of long-term foreign government bonds paid by issuance of short-term central bank reserves. The size of this FX intervention is set such that the real exchange rate path closely mimics the one achieved with the LSAP program. Thus, by design the real exchange rate paths in Figure 5 are closely aligned, but the remaining variables are fully endogenous in the model. Even so, Figure 5 documents that the response of long-term rates, and hence of output and inflation are approximatively identical in both experiments.

This result might be surprising as FX interventions do not affect the supply of domestic long-term assets available to the private sector. It is however a direct consequence of the market segmentation assumed in our model and the resulting tight link between the exchange and long-term rates as implied by the long-UIP condition (35). From the flow of funds perspective, note that FX interventions are sterilized, and hence involve purchases of foreign assets and issuance of domestic short-term bonds. The latter are not internationally tradable, and so must be absorbed by agents of the small open economy. This triggers portfolio rebalancing by its unrestricted households, which sell their long-term bonds to foreigners. Hence, unrestricted agents end up with less domestic long-term bonds on their balance sheets, just like when the central bank engages in LSAPs. As a consequence, the term premium responds similarly under both policies, and so they have similar effects on economic activity and inflation. It follows that the similarity in transmission of LSAP and FXI is not driven by a low calibrated value of ω_r (0.1, see Table 2) in our baseline model. If we increase the value of ω_r to (e.g. to 0.25 or higher), the impact on output by a given sized LSAP and FXI goes up commensurately.

Overall, this part of our analysis implies that LSAP within our small open economy framework transmits similarly to an FX intervention in that it triggers higher domestic economic activity and inflation mainly by depreciating the real exchange rate, consistent with the argument by Cwik and Winter (2024). Let us stress again that this result is conditional on the absence of additional FX market-specific frictions. Accordingly, it does not matter much in our small open economy model if the CB buys domestic or foreign long-term bonds, the macroeconomic impact will be about the same anyway as the exchange rate is the key propagation mechanism.

4. Case Study: Assessing the Impact of the Riksbank's Unconventional Monetary Policy

Building on these results, this section presents a case study evaluating the macroeconomic and fiscal impacts of the Riksbank's unconventional monetary policies—specifically, negative interest rate policies and large-scale asset purchases—implemented between 2015 and 2019. Using our calibrated model, we aim to uncover the effects of these policies. Other major central banks, like the European Central Bank, also engaged in UMP policies at the time, but confine ourselves to assessing the partial impact of Riksbank policies and hence do not consider international policy spillovers. However, we explore the pros and cons of an alternative domestic policy mix in which fiscal stimulus replaces the UMPs pursued by the Riksbank.

Section 4.1 outlines the methodology used to create a baseline scenario with Riksbank's LSAPs and short-term policy rates, which serve as the basis for the subsequent assessment of the macroeconomic impact of these policies. As will become clear when we describe how we measure and implement the monetary policy announcements in the model, we maintain the assumption that the UMP tools adopted by the Riksbank were discretionary in nature and hence not predominantly priced into market expectations before they were announced. This assumption is consistent with Riksbank policy rate forecasts and LSAP announcements in monetary policy reports, which neither projected that short-term policy rate would be cut further at any point in time during this period, nor that more LSAP would be needed. Although it is possible that markets at some points in time projected that the Riksbank would go more deeply negative with policy rates and do more LSAP, our assumption that all UMPs were discretionary will be conservative and lead to smaller measured effects.

Next, in Section 4.2, we use the calibrated model to run a certain number of counterfactual scenarios aimed at parsing out the total and partial impact of these unconventional policies. That is, we can report how macroeconomic developments would have unfolded in these years had the Riksbank not utilized these policy tools. Finally, in Section 4.3, we use the model to study the inflationary and fiscal consequences in a counterfactual scenario where we replace the Riksbank unconventional monetary policies 2015-2019 with a fiscal policy stimulus in the form of higher government spending. We size the fiscal stimulus to give the same path for output as the one the UMPs pursued by the Riksbank achieved during these years.

4.1 Scenario Design

Between 2015 and 2019, the Riksbank purchased government bonds on a large scale and implemented (mildly) negative short-term policy interest rate paths to counteract persistently below target inflation outturns and anchor inflation expectations at the target.

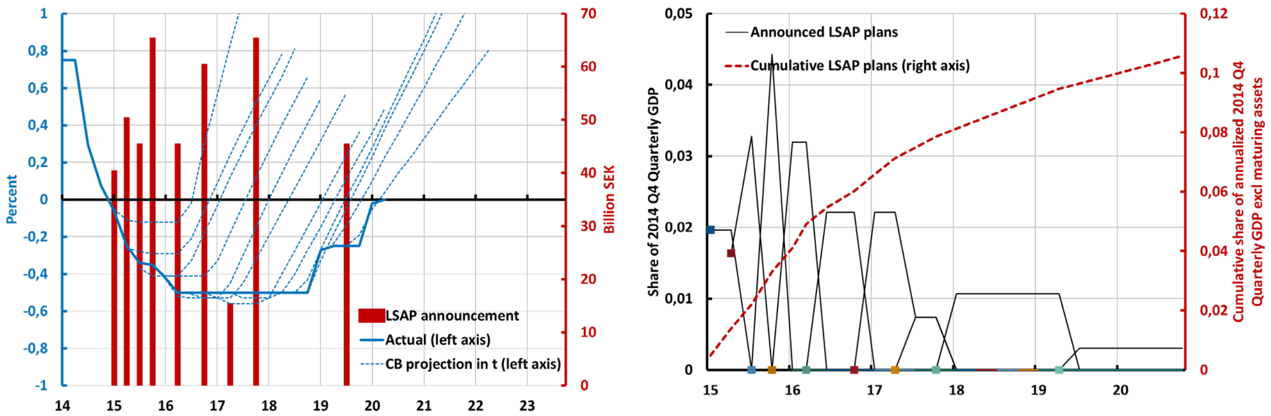
By autumn 2014, inflation in Sweden had been below the target of 2 per cent for several years and medium-term inflation expectations of market participants had drifted well below the Riksbank’s 2 percent inflation objective. In response, the Riksbank reduced its policy rate, or repo rate, to zero by October 2014, signalling a commitment to additional measures to make monetary policy more expansionary if necessary. Early in 2015, the Riksbank faced an increasingly uncertain global economic landscape, with monetary policies diverging across major economies. While the U.S. Federal Reserve moved toward a less expansionary stance, the European Central Bank (ECB) intensified its stimulus with an ambitious asset purchase program, announcing monthly purchases of EUR 60 billion in private and government securities intended to be carried out until at least September 2016. This divergence presented the risk of a stronger Swedish krona relative to the euro, potentially lowering import prices and further weakening domestic inflation.

To address these risks and support a sustained increase in inflation towards the target, the Riksbank lowered the repo rate to -0.10% in February 2015, marking Sweden’s first foray into negative interest rates. Alongside this rate cut, the Riksbank initiated government bond purchases, initially committing SEK 10 billion to enhance liquidity and exert downward pressure on longer-term interest rates (see Figure 6). These bond purchases were seen as necessary to reinforce the expansionary effects of the negative interest rate and help anchor inflation expectations around the 2% target.

Throughout 2015, the Riksbank expanded the asset purchase program significantly, conducting several rounds of bond purchases and lowering the repo rate further to -0.35% in July and -0.50% by early 2016. By the end of 2015, total bond purchase announcements had increased to SEK 190-200 billion, equivalent to more than 30% of Sweden's outstanding stock of nominal government bonds and about 5% of annual GDP.

The Riksbank's monetary policy stance remained notably expansionary into 2016 and 2017, as inflation showed a gradual increase but remained fragile. While economic conditions in Sweden and globally began to stabilize, the Riksbank continued to weigh the risks of adjusting policy prematurely. In early 2016, the Riksbank announced it would reinvest principal payments and coupon payments from its bond holdings, a decision aimed at stabilizing the size of its balance sheet. Moreover, in April 2016, the Riksbank broadened the scope of its purchases to include both nominal and inflation-linked government bonds, purchasing an additional SEK 45 billion in bonds over the latter half of 2016. By the end of 2017, cumulative bond purchases reached SEK 290 billion, comprising SEK 252.5 billion in nominal bonds and SEK 37.5 billion in inflation-linked bonds. These purchases represented approximately 39% of the outstanding stock of nominal bonds and about 20% of inflation-linked bonds, significantly expanding the Riksbank's balance sheet.

Figure 6. Riksbank Negative Policy Rates Forecasts and Announced Asset Purchase Plans.
Percent, SEK Billion, Share and cumulative share of 2014 quarterly GDP.



Notes: All LSAP announcements concern new purchases, except two cases. In December 2016, the Riksbank announced a SEK 30 billion purchase of nominal Swedish government bonds for January–June 2017, with reinvestments beginning in early 2017 and continuing throughout the year. In December 2017, the Riksbank decided to reinvest SEK 65 billion, starting in January 2018 and ending in June 2019. At the last monetary policy meeting just ahead of the scheduled end date of each ongoing asset purchase program, a new program was announced (disregarding reinvestment purchases that were announced in 2016Q4). These announcements, indicated by the squares in the right panel, marked a shift in the purchase plans. In the first two 2015 meetings, LSAP plans included the current quarter; in subsequent meetings, decisions focused on future quarters.

Source: Sveriges Riksbank.

By the end of 2017, as inflation approached 2%, the Riksbank gradually reduced its net asset purchases but continued reinvestments to maintain the program's overall expansionary impact. This mix of negative interest rates and extensive asset purchases underpinned the Riksbank's strategy to foster economic conditions conducive to price stability, illustrating the broader application of unconventional monetary tools in a small open economy.

The negative interest rate policy and LSAP announcements during 2015-2019 are shown in Figure 6.[22] The left panel shows the actual short-term policy rate (thick blue) along with the projected policy rate projection (thin dotted) at each policy meeting, The red bars also show the total amount of LSAP (billion SEK, displayed on the right axis) that was announced at each policy meeting during these years. By studying the policy rate projections, we see that the Riksbank not until 2017 communicated that they may cut the policy rate further (slightly below -0.5 percentage points). Before 2017, as the Riksbank ventured deeper and deeper into negative rates territory, the bank never projected it would cut the rate further. The bank also always communicated that it would start normalizing rates during the 3-year forecast horizon. That is, the Riksbank never communicated a flat nominal rate path. Most LSAP announcements happened 2015-2016, and only three additional LSAP programs announcements were announced thereafter (2017-2019). The right panel in Figure 6 shows how the LSAP purchases were communicated to be phased at each announcement. The early rounds were explicitly front-loaded, while subsequent purchases were phased in more gradually. It also shows that the cumulated announced LSAP plans slightly exceeded 10 percent of 2014 GDP by the end of 2019.

With these considerations in mind, we now discuss how we feed these policy announcements into the model to generate a macroeconomic scenario which captures a situation with below-target inflation, subdued economic activity where policy rates are driven negative and the central bank undertakes several rounds of LSAP to avoid further exchange rate appreciation, provide economic stimulus and nudge inflation closer to its target. The process involves careful modelling of asset purchase plans and economic conditions as they unfolded over time, allowing for a detailed analysis of policy impacts. Here's how our simulation set-up was carried out:

1. **Setting the economic state in 2014**: The simulation initializes in the fourth quarter of 2014, setting the economic state to reflect the period just before the negative interest rate period came into effect and the potential for the zero lower bound (ZLB) to become binding. Establishing this state accurately is essential to recreate the economic environment at the time and allows for more realistic policy comparisons in the following periods. We do this by choosing the domestic and foreign discount factor shocks ε_t^d and ε_t^{d*} to match the level of the Riksbank's policy interest rate in 2014Q4. This state is associated with projected inflation below the central banks' target and economic slack.

2. **Replicating LSAP plans**: Starting in the first quarter of 2015, we sequentially replicate the asset purchase plans as they were announced by the Riksbank in Figure 6. This step involves introducing the expected asset purchase shocks, $\varepsilon_t^{QE}, \varepsilon_{t+1}^{QE},.., \varepsilon_{t+n}^{QE}$, into the model that align with the timing, scale, and length of these LSAP

[22] We have taken these policy rate projections and LSAP announcements from the Riksbank monetary policy reports. In cases where two monetary policy reports are issued the same quarter, the figure reports the policy rate path from the last report this quarter. Note that on certain occasions, such as in the April and July reports of 2017, the policy rate forecast remained unchanged. As a result, some of the policy rate forecasts in the left-hand panels overlap. In case several LSAP announcements were provided in a quarter, the figure reports cumulated quarterly numbers on the right axis. This happened only once, namely in 2014Q1 when 10 billion was announced on 11 February 2015 and 30 billion on 18 March 2015. Hence the first bar equals 40 billion in 2014Q1.

announcements. This method allows the simulation to approximate how these purchases influenced market expectations and economic conditions in real-time, closely mirroring the original intent of the policy announcements.[23]

3. **Phasing in NIRP and adverse demand shocks**: Starting in the first quarter of 2015, we introduce an adverse demand shock in the current quarter to align the model with the Riksbank's announced duration of an effective lower bound (ELB) on the policy rate (minus 10 basis points at the time). Specifically, we choose the domestic and foreign discount factor shocks ε_t^d and ε_t^{d*} and the effective lower bound in the model, λ_t, by minimizing the distance between the model implied interest rate path for the coming 12 quarters and the Riksbank's announced interest rate path and all known LSAP announcements up to this point.[24]

4. **Repeating Steps 2 and 3 for all quarters 2015-2019.** Then we step one period ahead to the second quarter of 2015 and repeat the exercise. We do so repeatedly for all quarters between 2015Q1 and 2019Q2. Note that we add the Riksbank announcements of asset purchase plans in the quarters when they were announced. This yields a series of adverse discount factor shock ε_t^d and ε_t^{d*} and effective lower bounds λ_t conditional on all communicated LSAP announcements up to the quarter at hand.

5. **Simulating counterfactual scenarios**: We undertake a number of counterfactual scenarios to assess the impact of LSAPs and NIRP policies. These scenarios explore what economic outcomes might have occurred if asset purchases had not been implemented and if the ELB had remained non-negative. The experiments are conditioned on the domestic and foreign demand shocks we have optimized to fit the actual and projected Riksbank policy rate forecast in quarter t=2015Q1,….,2019Q2, Specifically, the following three distinct counterfactuals are run:

A. LSAP = 0 and ELB < 0: This scenario assumes that no asset purchases were conducted, but the policy rate was still allowed to drop below zero. This scenario isolates the effects of a negative ELB without LSAP support. We implement this scenario by enforcing the same string of negative demand shocks and similarly excluding the asset purchase announcements.

B. LSAP > 0 and ELB = 0: This scenario assumes active asset purchases but a binding ELB at zero interest rate. By holding the ELB at zero, it illustrates a world where only the Riksbank's LSAPs were deployed.

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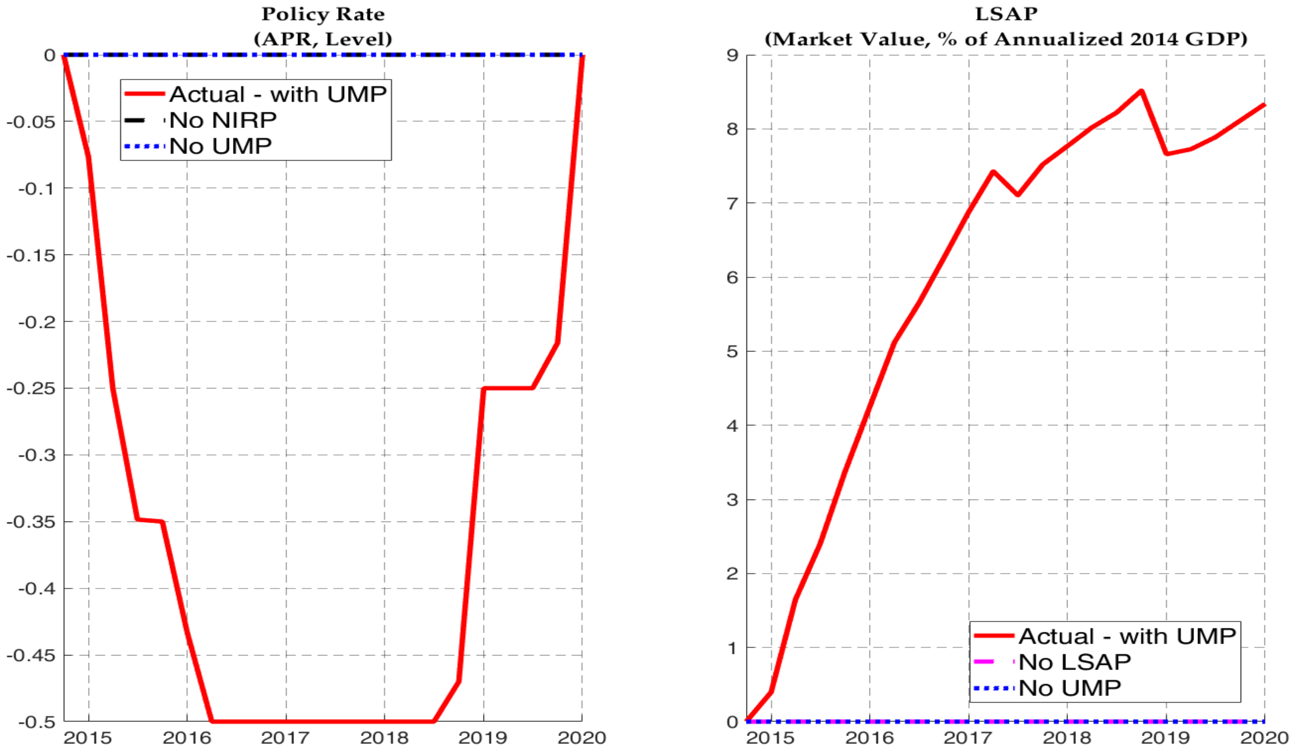
[23] Throughout this period the Riksbank consistently announced purchase plans for one to six quarters ahead. For example. in April 2016 the Riksbank announced the following plan for the coming two quarters: "The Executive Board decides that during the period July-December 2016, the Riksbank will purchase nominal Swedish government bonds for a nominal amount of SEK 30 billion over and above purchases of nominal Swedish government bonds decided earlier. During the period June-December 2016, the Riksbank will purchase real Swedish government bonds for a nominal amount of SEK 15 billion".

[24] Hence, the ELB variable λ_t in $R_t = max\{\lambda_t, \tilde{R}_t\}$ is allowed to vary from period to period.

C. No UMP (LSAP = 0 and ELB = 0): This scenario assumes neither asset purchases nor a negative policy rate. By holding both asset purchases and the ELB at zero, it illustrates a world where the Riksbank's unconventional policy tools were not deployed, giving insight into how the economy might have evolved under more traditional policy constraints.

All told, these counterfactual simulations – shown graphically in Panel A in Figure 7 – allows us to assess the total impact of Riksbank UMPs, as well as the relative contribution of asset purchases and negative interest rates, on the economy during this period.

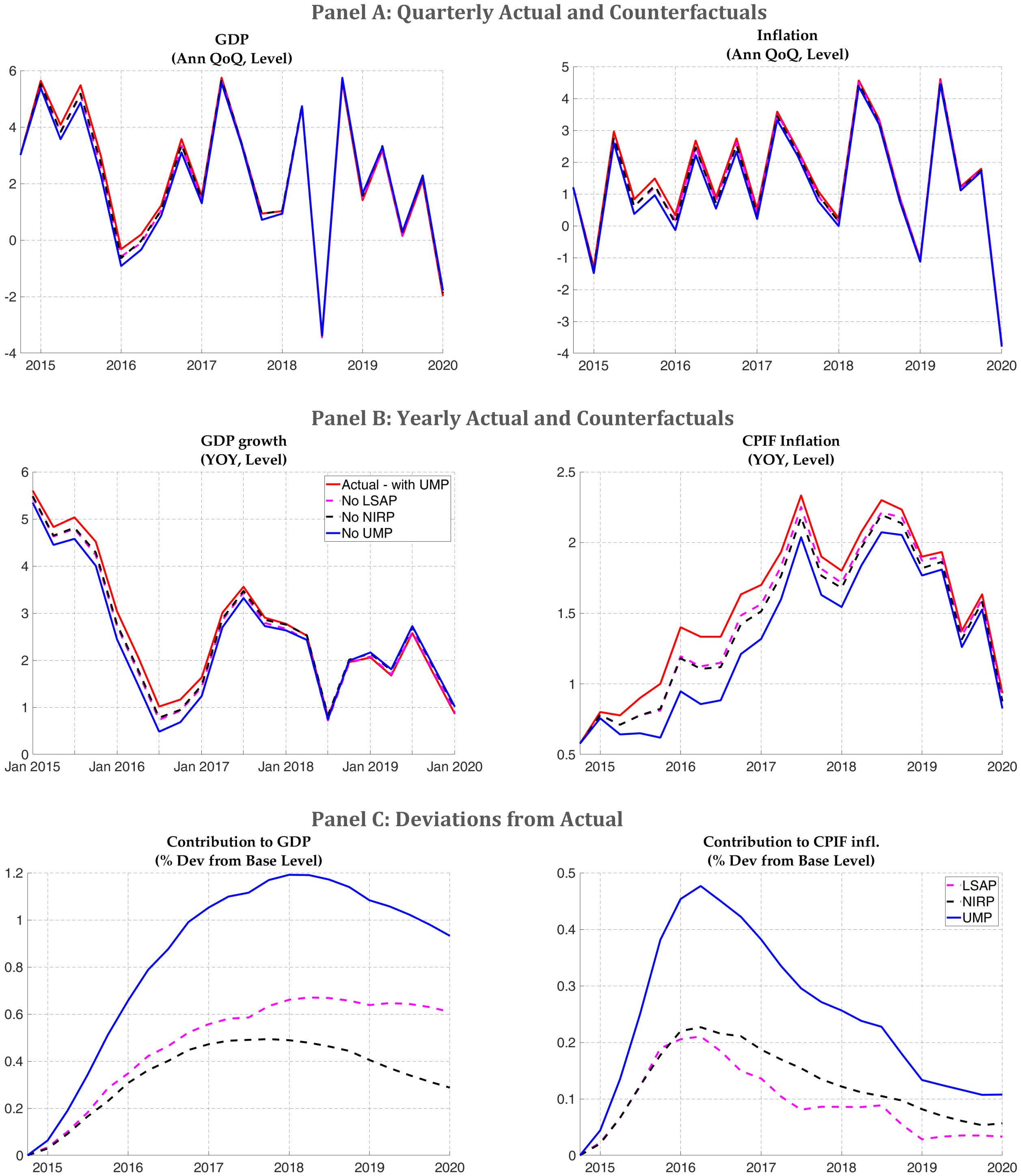
Figure 7. Counterfactual Scenarios of Riksbank Unconventional Monetary Policies 2015–2019.



Notes: The left panel depicts the policy interest rate implemented by the Riksbank (red solid line) as well as the counterfactual zero lower bound (black dashed and blue dotted lines). The right panel depicts the asset purchases that the Riksbank implemented including maturing assets (red solid line) and the counterfactual scenario without any asset purchases (magenta dashed and blue dotted lines).

An important underlying assumption in our counterfactual analysis is that the gradual implementation of LSAP and NIRP policies were not anticipated in advance by households and firms. This assumption is supported by market expectations on policy rates and LSAP. In December 2014 market pricing was such that policy rates were not expected to become negative, and they did not envision that the Riksbank would launch a substantial LSAP program. These expectations were subsequently adjusted, but our maintained assumption that the intensification of these measures come as surprises imply that we make a conservative assessment of the effectiveness of these policies in our forward-looking model framework. This is an important consideration to keep in mind in the subsequent quantitative analysis.

Figure 8. Impact of Riksbank UMP on GDP and Inflation in Sweden 2015–2019.



Notes: Panel A displays annualized quarter-on-quarter GDP growth and CPIF Inflation 2014Q4 to 2020Q1 (red solid lines). The other three lines represent outcomes under (i) no LSAP (magenta dashed lines), (ii) no NIRP (black dashed lines), or (iii) neither of these policies (blue solid lines). Panel B displays same results for year-on-year (i.e. four-quarter) changes. Finally, Panel C represents counterfactual scenarios (actual minus scenarios without various policy measures) documenting the contribution of (i) LSAPs (magenta dashed lines), (ii) NIRP (black dashed lines), or (iii) both these policies (UMP, blue solid lines).

4.2 Macroeconomic Effects of Riksbank Unconventional Monetary Policies 2015-2019

We now quantify the macroeconomic effects of the nine asset purchase programs and twelve policy interest rate forecasts, 8 of which indicated a lowering of the effective lower bound from zero to -0.56 percent.

Panel A in Figure 8 presents the annualized quarter-on-quarter growth rates of real GDP (left panel) and the CPIF price level (right panel) 2014Q4 to 2020Q1.[25] The red solid lines represent actual observed data, while other lines illustrate counterfactual scenarios in the absence of specific unconventional monetary policies: (i) no negative interest rate policy (NIRP; black dashed lines), (ii) no large-scale asset purchases (LSAPs; magenta dashed lines), and (iii) neither NIRP nor LSAPs (blue solid lines). While the blue solid line shows that CPIF inflation and GDP growth would have been lower in the absence of any UMPs, a striking feature from the charts in Panel A is that the positive gradual impact of the UMPs is swamped by other fluctuations. Hence, the positive impact of UMPs is challenging to filter out in real time, and these patterns can lead central bank staffers and others to erroneously draw the conclusion that LSAPs and NIRP are ineffective in stimulating GDP growth and inflation, which would question their usefulness for inflation targeting. The risk for mistakes of this kind is especially elevated in a forecasting process which focuses on forecast revisions between monetary policy reports.

The charts in Panel B in Figure 8 present year-on-year (i.e. 4-quarter) changes in GDP growth rates (left column) and CPIF inflation (right column). The red solid lines represent the actual observed data, while the other three lines depict our counterfactual scenarios. When studying transmission to the year-on-year changes, which filters out some of the high frequency idiosyncratic movements, our simulations demonstrate a notable yet modest transmission of LSAPs and NIRP on GDP growth and inflation, consistent with prior event studies of Swedish LSAPs and conventional monetary policy shocks.[26]

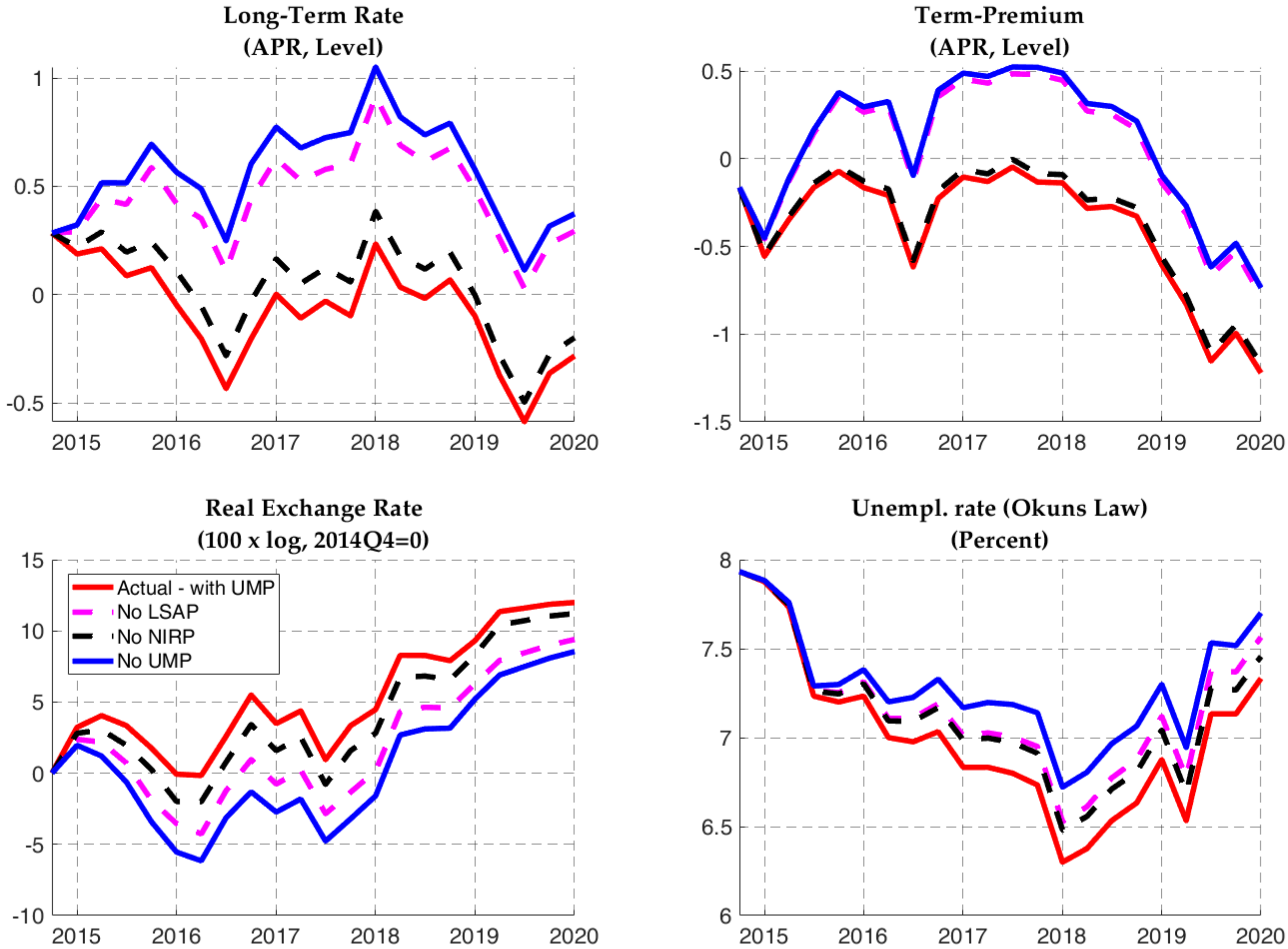
Moreover, the charts in Panel C reveal non-trivial medium-term effects of these policies. Over time, the contribution to GDP (cumulating growth rates) exceeds 1 percent, and the impact of the year-on-year inflation is close to 0.5 percentage points in early 2016, with an associated impact on the price level exceeding 1.25 percent. Both LSAPs (magenta dashed lines) and NIRPs (black dashed lines) made meaningful contributions to the total impact of UMP tools (blue solid lines). These larger accumulated effects underscore the importance of considering level dynamics when evaluating unconventional policies and imply that LSAPs and NIRP played an important role in achieving sustained improvements in economic and fiscal conditions, even if their immediate impact may appear modest.

Our results highlight the challenges of relying solely on short-term event studies to assess the effectiveness of UMPs. By focusing on cumulative contributions, it becomes clear that LSAPs and NIRP have significant

[25] In Sweden, the most commonly used measure of inflation is the Consumer Price Index (CPI), which reflects general price changes for goods and services purchased by households. However, since the CPI is influenced by interest rate adjustments—particularly those affecting housing loans—an alternative measure known as the CPIF (CPI with a fixed interest rate) is also used. This index tracks the same price changes as the CPI but excludes the direct impact of monetary policy on interest costs. As of September 2017, the Riksbank replaced the CPI with the CPIF as its official inflation target.
[26] See section 4.3 in Andersson et al. (2022) for a summary of the limited research on asset purchases and their impact on output and inflation in Sweden.

medium-term economic implications, providing essential support for output and inflation and better target fulfilment for the central bank. And it should be noted that the cumulated effects we report in Figure 8 are conservative as the convex “banana-shaped” Phillips curves embedded into our nonlinear model then implies smaller effects on inflation of the UMP tools than a standard linearized solution.[27]

Figure 9. Transmission of Riksbank UMP to Financial and Labor Markets in Sweden 2015–2019.



Notes: The red lines in the figure display Adrian, Crump, and Moench (ACM) model-implied five-year yield, the ACM five year term premium, the trade weighted (KIX "the krona index") real exchange rate (+ is depreciation relative to 2014Q4) and the unemployment rate. The other three lines represent the following counterfactual scenarios: (i) no LSAP (magenta dashed lines), (ii) no NIRP (black dashed lines), or (iii) neither of these Riksbank policies (blue solid lines). The counterfactual term premiums are obtained by shifting the ACM premiums observed in the data using the model-implied reactions of this variable to the considered scenarios. The counterfactual unemployment rates are derived from an estimated Okun's law relationship $\Delta u_t = \beta(L)\Delta y_t + \varepsilon_t$ on Swedish quarterly data from 2001-2023. The estimation has an R^2 of 0.58, and the estimated parameters for the lags are -0.102, -0.106, -0.021, -0.078, and -0.055, respectively.

Figure 9 illustrates key aspects of the transmission of UMPs. The upper panels display the Adrian, Crump, and Moench (2013) (ACM) model-implied five-year yield (top left), the ACM five-year term premium (top right), whereas the bottom panels show the trade-weighted real exchange rate (bottom left), and the unemployment rate (bottom right).

[27] We have redone the simulations in Figure 8 with linearized variant of the model and in this case we get notably larger – about twice as high – effects on inflation and output of both UMP tools as reported in Figure 8.

The top interest rate panels show that UMP, especially LSAPs, contributed to reducing long-term rates and the term premium notably during the period. Quantitatively, the results suggest that UMPs contributed to a reduction of approximately 1 percentage point in the five-year yield and around 50 basis points in the term premium. Given LSAPs close to 10 percent of GDP, these findings are consistent with prior studies on the effects of unconventional policies, including those on advanced economies like the euro area (e.g., Altavilla et al., 2015) and the United States (e.g., Gagnon et al., 2011), as well on studies on Swedish data (Beechey and Gustavsson 2023 and Christensen and Xin Zhang 2024) which report yield declines of similar magnitudes in response to large-scale asset purchases and forward guidance.[28]

The bottom left panel (real exchange rate) highlights the role of UMPs in depreciating the Swedish krona. The sustained depreciation with more than 5 percent increases prices of imported goods and improves the competitiveness of Swedish exporting firms. The exchange rate pass-through to import prices is particularly relevant in small open economies like Sweden, where import is a significant share of total consumption. A UMP driven weaker exchange rate boosts net exports (see Figure 2) and domestic labor demand. This leads to higher domestic and imported price inflation, which brings CPIF inflation closer to the 2 percent inflation target. The larger depreciation observed under the actual trajectory (red line) compared to counterfactual scenarios without UMPs underscores the importance of the exchange rate as a transmission channel, and it can be noted that LSAPs weakened the real exchange rate much more than negative policy rates, but both tools contributed equally to lower unemployment rate according to our counterfactual analysis. This is because LSAPs work mainly by via net exports, whereas NIRPs mainly work by boosting domestic demand as can be seen from Figure 2.

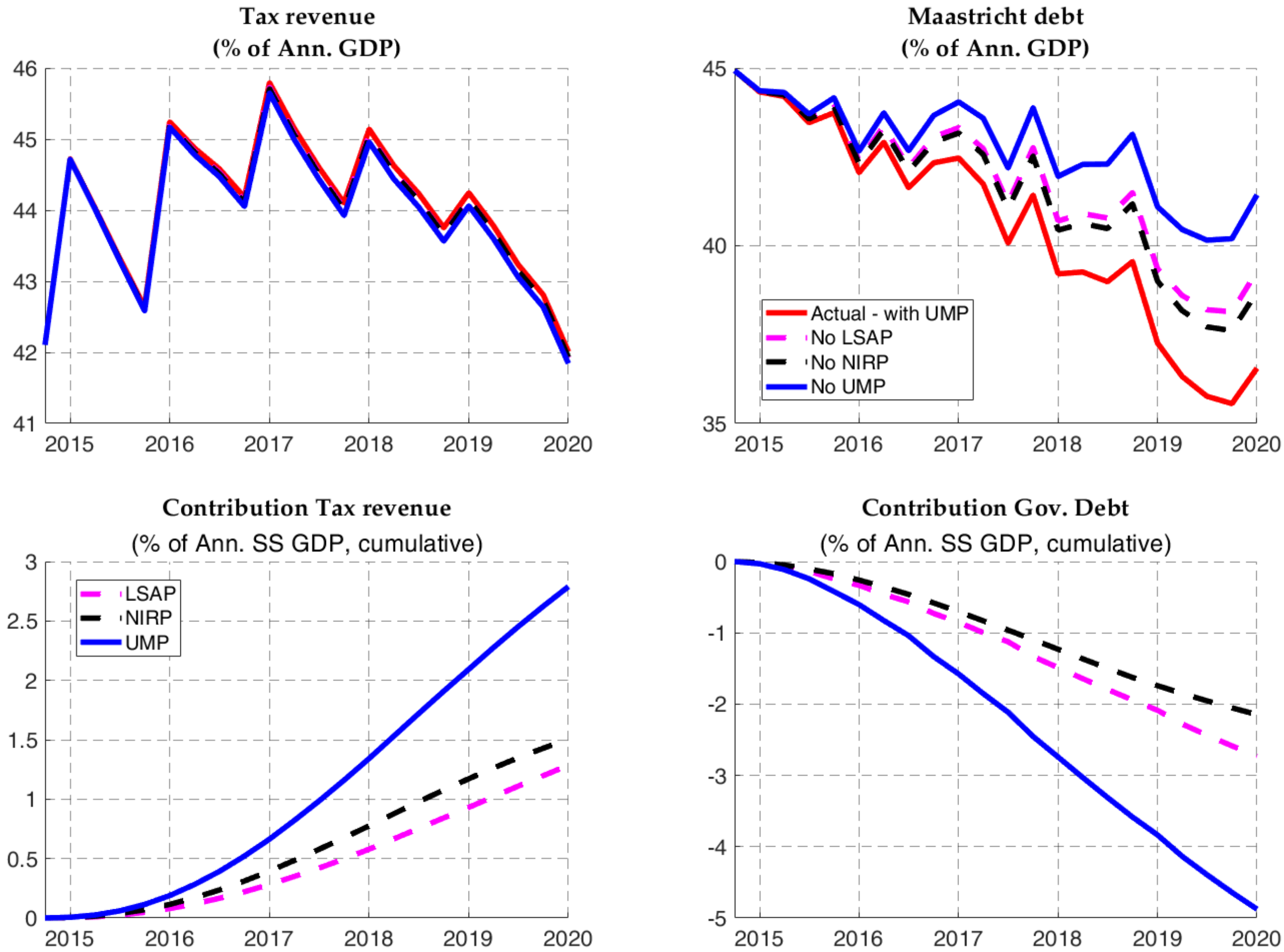
Figure 10 shows the fiscal implications of the Riksbank UMPs. As before, the red solid lines represent observed data in the upper panels, while the black dashed, magenta dashed and blue solid lines depict the counterfactual scenarios. The top panels show tax revenue and government debt as a percentage of GDP in levels, while the bottom panels show the contribution of the measures to cumulated tax revenues and government debt. While the upper left panel suggest that the contribution to period-by-period tax revenues is small, the lower left panel reveals that the contributions of Riksbank UMPs to tax revenue become sizable when cumulated over time. By end-2019, the cumulative contribution of LSAPs and NIRP combined amounts to approximately 2.5% of trend GDP.

The red solid line in the upper right panel depicts the actual Maastricht debt-to-GDP ratio, which has fallen from an initial level of 45 to about 37 percentage points during the 2015-2019 period. The counterfactual blue dashed line shows that UMPs by the Riksbank has contributed materially – with nearly 5 percentage points – to the decline in the consolidated public debt position by the end of 2019. That is, without the Riksbank UMPs,

[28]Beechey and Gustavsson (2023) find a significant decline in term premia on Swedish government bonds as bond supply decreased. Even after accounting for the state of the business cycle and international financial conditions, their estimates suggest that the Riksbank's government bond purchases between 2015 and 2021 reduced term premia by a total of 0.4 to 1.0 percentage points.

government debt would have remained well above 40 percent of GDP. The bottom-right panel confirms that both unconventional monetary policy tools contributed to the reduction in government debt as a percentage of trend GDP. The reduction in the consolidated government debt position is primarily driven by two factors, higher tax revenues and lower debt service costs.

Figure 10. Fiscal Effects of Riksbank Unconventional Monetary Policies in Sweden 2015–2020.



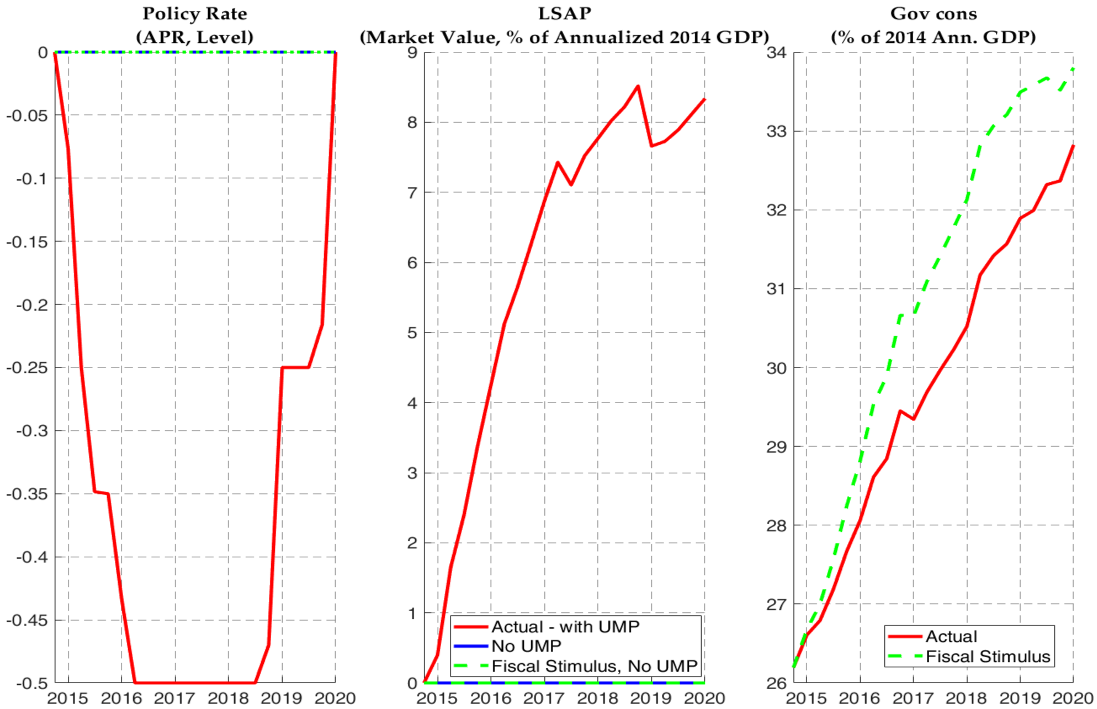
Notes: The figure displays tax revenue and the Maastricht debt as a percent of GDP in Sweden from 2014Q4 to 2020Q1 (red solid lines). The other three lines represent counterfactual scenarios: (i) no LSAP (magenta dashed lines), (ii) no NIRP (black dashed lines), or (iii) no UMP (neither LSAP nor NIRP, blue solid lines). The bottom panels show contribution of various policy measures (actual minus scenario without policy measure) to tax revenues and government debt.

These findings provide context for the subsequent losses on LSAP during the pandemic. Our conservative counterfactual analysis suggests that the consolidated gains from the Riksbank unconventional policies 2015-2019 paid for the subsequent central bank losses several times over. Therefore, we believe it is misleading to argue as in SOU 2023:85 (2023) that the Riksbank LSAPs were associated with large fiscal costs. Even so, this does not imply that LSAP is always a free lunch. Had the recovery been faster than expected during this period, the central bank losses on the LSAP portfolio could have been notably larger and it's even possible that the impact on the consolidated public fiscal position could have been negative (see Adrian et al., 2024). Still, our analysis suggests that the losses by the central bank should be weighed against the tax revenues and lower debt service costs implied by unconventional monetary policies. The macroeconomic benefits and fiscal costs of unconventional policy should also be weighed against the costs and benefits of alternative means to stimulate the economy, as we will discuss next.

4.3 Counterfactual where Conventional Fiscal Stimulus Replaces Riksbank UMPs

In this section, we present the fourth and final counterfactual scenario, in which conventional fiscal policy replaces Riksbank unconventional monetary policies (UMPs) during this episode. Specifically, we analyze a fiscal-only intervention scenario, in which large-scale asset purchases (LSAP = 0) and negative interest rates (ELB = 0) are replaced by higher government spending (G > 0) – see Figure 11.

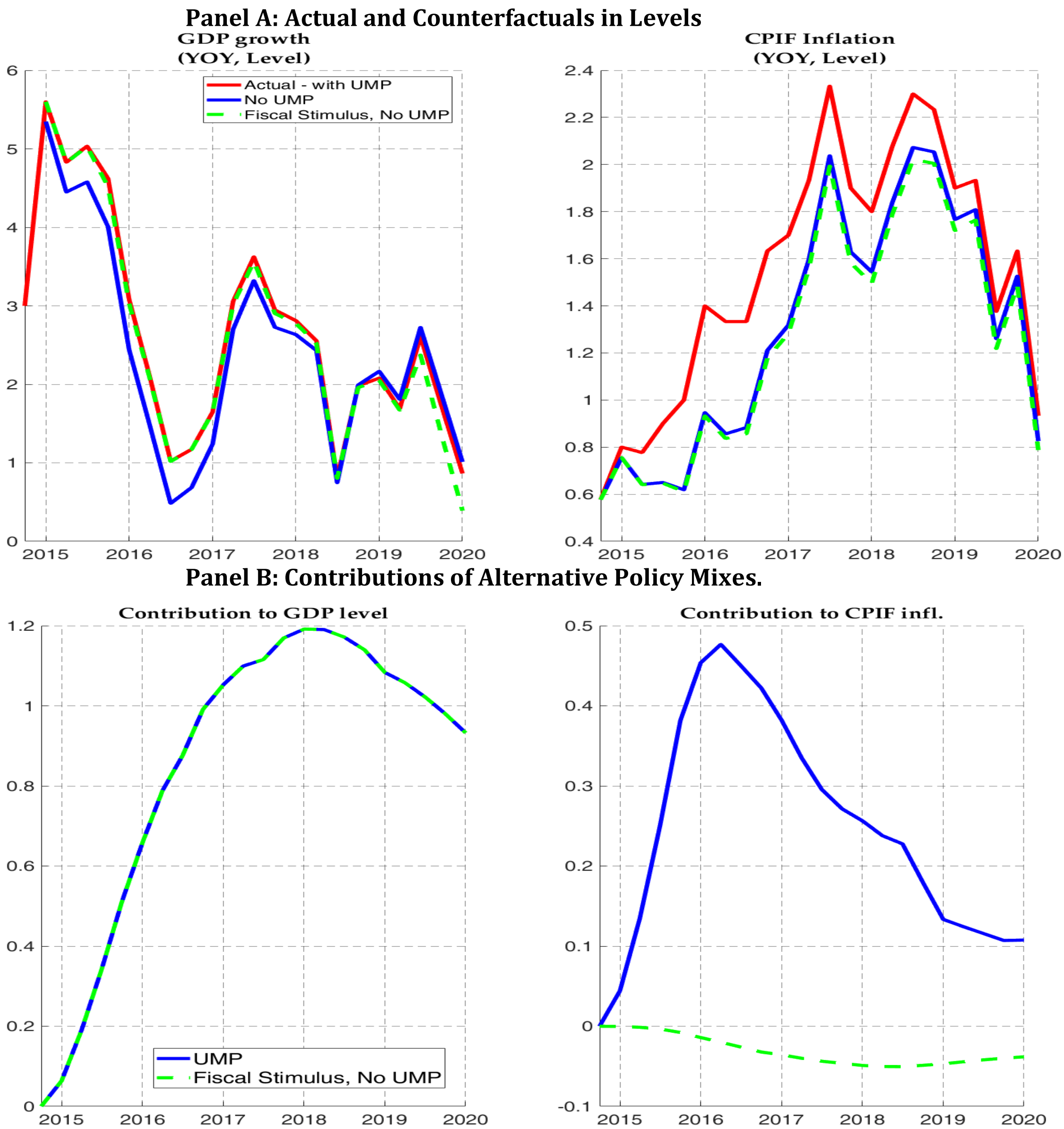
Figure 11. Counterfactual Fiscal and Monetary Policy Mixes 2015-2019.



Notes: The left/middle panel shows the policy interest rate (red solid line) alongside with counterfactual zero lower bound scenarios (blue solid and green dashed lines). The middle panel illustrates same policy for the Riksbank's asset purchases. The right panel presents government consumption in Sweden as a percentage of 2014 annual GDP (red solid line) and a path with higher government spending (green dashed line) that mimics the same output path ass unconventional monetary policy.

This scenario seeks to address the question: What if fiscal policy had been the sole instrument used to stabilize the economy instead of any UMP measures? To ensure comparability, this analysis adopts the same initial state as in the previous scenarios, beginning in 2014Q4, and incorporates the same sequence of adverse shocks observed between 2015Q1 and 2019Q2. We impose no UMP measures, setting both LSAPs and the ELB to zero. The policy response, therefore, is limited to government spending hikes. The key methodological step involves iteratively from 2015Q1 to 2019Q2 determining the path of government consumption (g_t) necessary to replicate the path of output observed under UMP measures (i.e. actual data). This sequential search allows us to isolate the fiscal response required to achieve an equivalent level of output stabilization in the absence of any unconventional monetary policy tools. The right panel in Figure 11 shows that government consumption in the counterfactual scenario needs to be increased with a little more than 1 percent over time to replicate the gradual percent output expansion with a peak of 1.2 percent under Riksbank UMPs (Panel C in Figure 8). Hence, our model implies a fiscal multiplier around unity.

Figure 12. Macroeconomic Effects of Alternative Monetary Policy and Fiscal Policy Mix 2015–2019.



Notes: The red line figure in the upper panels show actual year-on-year GDP growth and CPIF inflation in Sweden from 2014Q4 to 2020Q1. The other two lines illustrate counterfactual scenarios relative to the actual data: (i) if the Riksbank had not implemented unconventional monetary policies (UMP) and (ii) if no UMP had been implemented, but fiscal policy (government consumption) was used to achieve the same increase in output as UMP. The bottom panels show contributions of alternative policy mixes to GDP in levels and year-on-year CPI inflation.

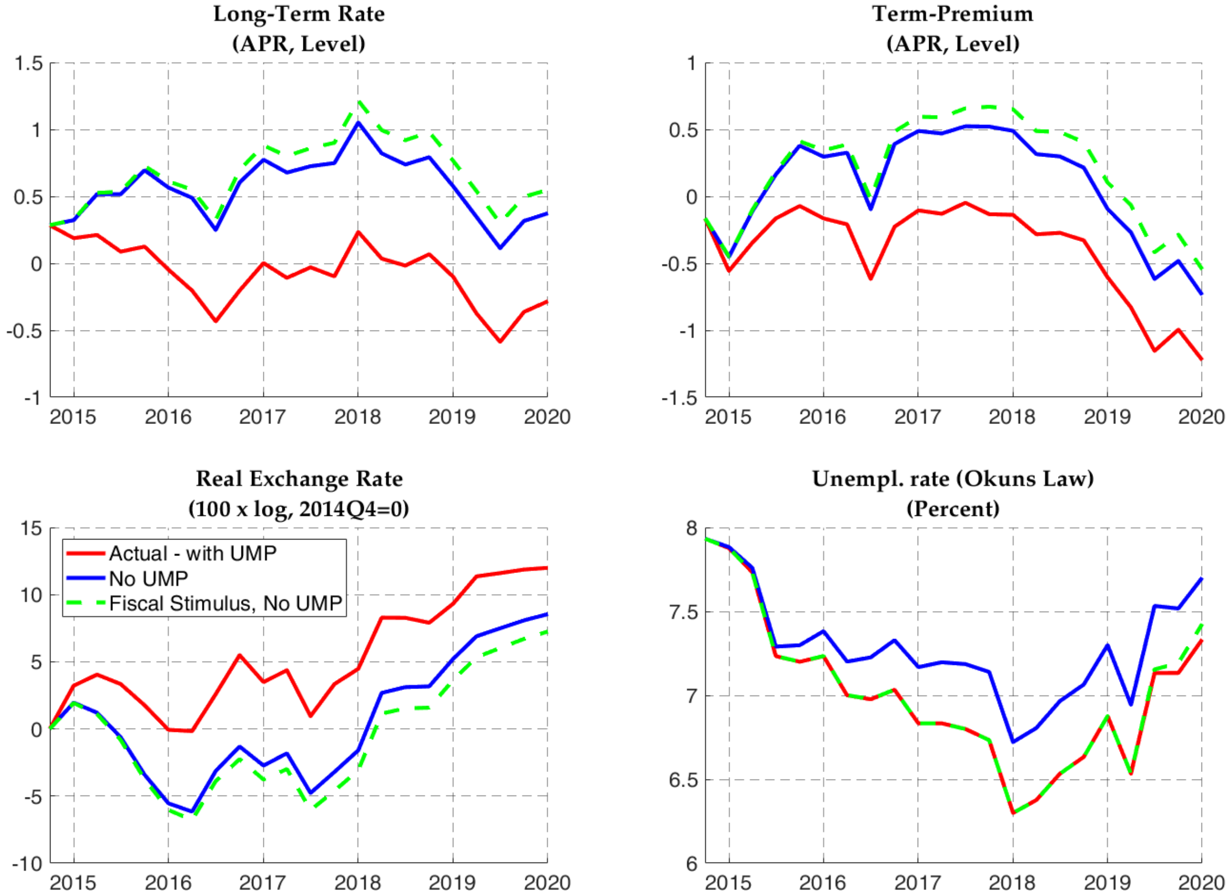
Figure 12 provides a comparative analysis of unconventional monetary policy (UMP) and fiscal policy, presenting year-on-year growth rates (panel A) and cumulative contributions (panel B) of real GDP (bottom row) and the CPIF price level (top row) in Sweden during the period from 2014Q4 to 2020Q1. As in previous figures, the red solid lines represent the actual observed data, while the other lines illustrate outcomes under the counterfactual scenarios. As can be seen in the lower left panel, the contribution to GDP is, by design, identical across the two scenarios with alternative monetary-fiscal policy mixes.

In levels, the upper left panel shows the actual data (solid red line) contains the baseline with Riksbank UMP, and when Riksbank UMP is removed we obtain the solid blue line with persistently lower output growth. We also see from the upper right panel that without Riksbank UMPs we get a notably lower inflation path during this period. When we add fiscal stimulus to the scenario without Riksbank UMPs, we get the actual output growth path back as shown by the green dashed line in the upper left panel, and the lower left panel shows that fiscal stimulus gives the same contribution to the output path as UMPs when measured as the deviation from a counterfactual scenario without any monetary-fiscal stimulus. Hence, it is important to understand that the green dashed line illustrates the outcomes of the fiscal policy interventions rather than the implications of an absence of fiscal policy.

However, a striking feature of Figure 12 is that the inflationary impact of fiscal policy interventions, although sized to provide the same output boost as Riksbank UMPs, is notably less favourable. In particular, the upper and lower right panels show that the fiscal interventions result in lower CPIF inflation relative to the scenarios without any fiscal support. This is consistent with the transmission of fiscal policy in Figure 2, although government consumption here is assumed to follow an AR(1) process to boost the fiscal output multiplier (and hence increase the scope for it to be successful). Even so, given that the policy rate is constrained by the ZLB for a protracted period of time it may be surprising that fiscal stimulus do not trigger higher inflation. There are two key mechanisms behind this finding. First, cognitive discounting and Kimball aggregation implies that conventional fiscal stimulus is much less effective at the ZLB than in a standard New Keynesian (actual and expected inflation move less).

The second key mechanism behind this finding is that conventional fiscal stimulus, undertaken in isolation by a small open economy, is not an effective way to drive up inflation due to the exchange rate channel. When the central bank loosens monetary policy, the domestic currency depreciates, which raises inflation not only through increased domestic demand but also via higher import prices. In contrast, the lower left panel in Figure 13 shows that fiscal stimulus worsens the country's external balance and strengthen the exchange rate, as the domestic interest rate differential relative to the rest of the world widens. This appreciation of the currency, driven by fiscal stimulus by one small country in isolation, offsets some of the inflationary impact of fiscal loosening, consistent with the findings of Dao et al. (2023) and Chen et al. (2023). And given calibrated sizeable trade shares and exchange rate pass through, fiscal stimulus in our model in fact leads to an overall CPIF inflation reduction, as the boost to domestic prices is more than offset by lower prices on imported goods. Even so, the upper panels in Figure 13 shows that fiscal stimulus leads to slightly higher term-premiums and long-term yields by driving up issuance of long-term bonds in the economy. However, the lower right panel shows that unemployment rate is about the same, as the Okun’s law we use applies to the actual output path.

Figure 13. Financial and Labor Market Effects of Alternative Fiscal and Monetary Policy Mixes 2015–2019.



Notes: The figure displays Adrian, Crump, and Moench (ACM) model-implied five-year yield, the ACM five year term premium, the trade weighted (KIX "the krona index") real exchange rate (a decline represents a real appreciation) and the unemployment rate. The other two lines illustrate counterfactual scenarios relative to the actual data: (i) if the Riksbank had not implemented unconventional monetary policies (UMP) and (ii) if no UMP had been implemented, but fiscal policy (government consumption) was used to achieve the same increase in output as UMP. The counterfactual unemployment rates are derived from an estimated Okun's law relationship $\Delta u_t = \beta(L)\Delta y_t + \varepsilon_t$ on Swedish quarterly data from 2001-2023. The estimation has an R^2 of 0.58, and the estimated parameters for the lags are -0.102, -0.106, -0.021, -0.078, and -0.055, respectively.

There is another subtle, yet instrumental, difference between monetary and fiscal policy when we normalize the alternative policy mixes to achieve the same output levels as is done in Figure 12. When monetary policy is used to stimulate output, the resulting output boost is also an increase in the output gap, as both negative interest rates and LSAPs leave potential output unchanged. But fiscal stimulus via higher government consumption takes real resources into account. This increase in spending is associated with an increase in potential output as well.[29] This implies that the output gap increases less under fiscal stimulus compared to UMPs as we normalize the experiment by the same stimulus to actual output. The smaller increase in the output gap under fiscal stimulus means less upward pressure on wages and domestic inflation than monetary policy stimulus, regardless of the differing exchange rate paths.

[29] Potential output is here defined as the level of output that would prevail if prices and wages is fully flexible, i.e. it resembles output in real models analyzed by Kydland and Prescott (1982), and Christiano and Eichenbaum (1992). It does not matter for our argument if we consider an efficient or distorted steady state, see Benigno and Woodford (1993) or Debortoli et al. (2019) for further details.

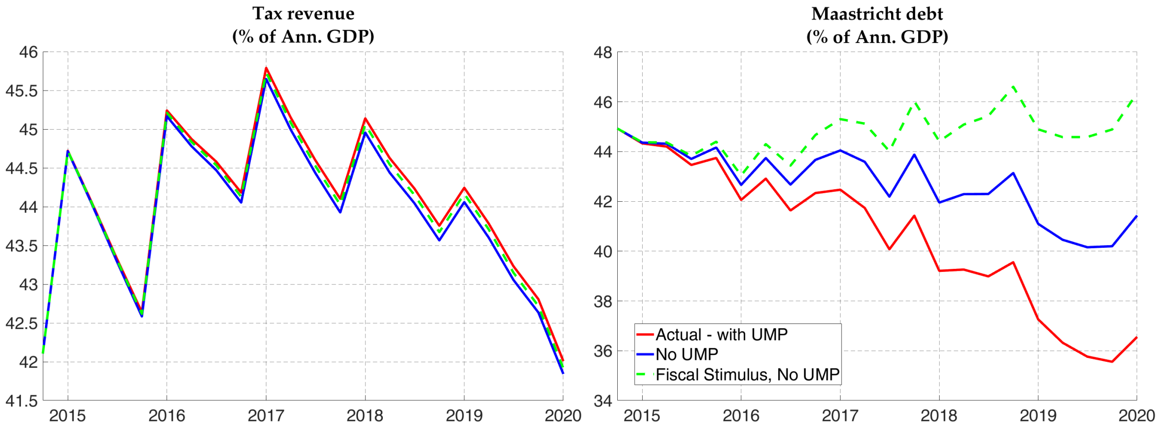
Figure 14 reports the fiscal implications of alternative fiscal and monetary policy mixes 2015–2019. As before, the red solid lines represent observed data in the upper panels, while the blue and green dashed lines depict the counterfactual scenarios.

Panel A in Figure 14 shows tax revenue and consolidated government debt position as a percentage of GDP in levels, while the bottom panels show the contribution of the alternative policy mixes to cumulated tax revenues and consolidated government debt. Our calibration of the government tax rule (eq. 17) parameters in Table 3 implies that labor income taxes adjust gradually to return the consolidated government debt level to its target (the so-called debt anchor, which equals 35 percent of annualized GDP) in the long-term. This setup is intentional and allows us to trace out the implications for consolidated debt of alternative policies without having the results affected by differing endogenous movements in labor income tax rates. By implication, any fiscal deficit is almost exclusively financed through debt issuance in the short term. As a result, debt rises significantly under the fiscal scenario, as the higher fiscal spending path in Figure 11 is associated with substantial fiscal costs when accumulated. The counterfactual green dashed line in the lower right panel shows that fiscal stimulus in lieu of Riksbank UMP would have materially increased the consolidated public debt position with nearly 5 percentage points by the end of 2019. By implication, without Riksbank UMP, a commensurate fiscal expansion to keep output and the unemployment rate at the same level prevailing under the Riksbank's UMP, would have resulted in unchanged consolidated government debt level as can be seen from the upper right panel in Figure 14, i.e., about 10 percent higher than the actual debt level prevailing by the end of 2019. Alternatively put, the Riksbank UMP improved the consolidated debt position by roughly 10 percent of GDP when we condition on conventional fiscal policy to achieve the same output path.

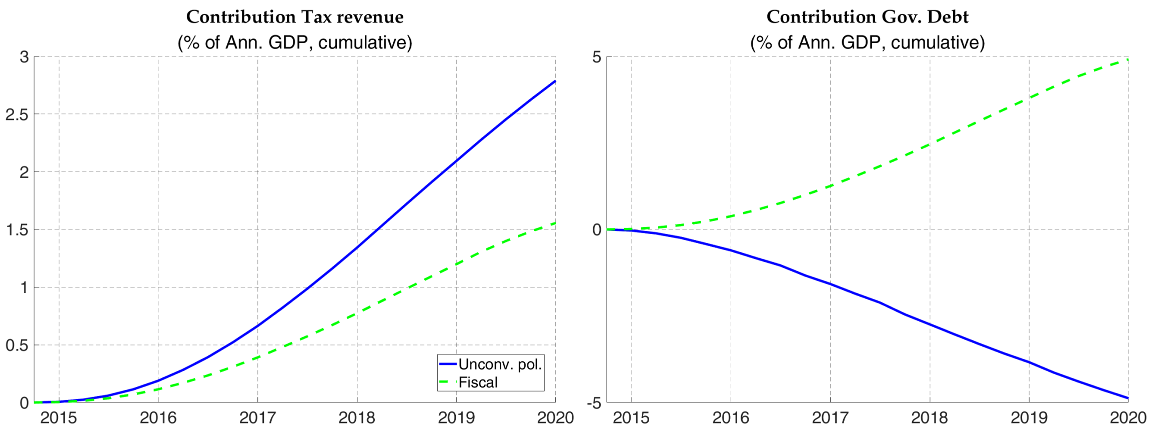
One interesting aspect in Figure 14 is that alternative fiscal-monetary policy mixes that leads to the same output path is associated with alternative fiscal consequences: i.e. the consolidated government debt position is weakened notably if conventional fiscal policy is used to stimulate the economy while it is improved if the Riksbank adopts NIRP and LSAP to stimulate economic activity commensurately. The bottom panels in Figure 14 cast light on this by decomposing the drivers of debt in the two counterfactual simulations shown in the middle right panel. This decomposition is helpful to understand why the consolidated position is impacted more adversely under fiscal stimulus. Obviously, a key source of budgetary costs under higher government spending is the direct resources used to pay for the stimulus. Over time, this cost adds up to nearly 5 percent of baseline GDP. And with central bank UMPs, this cost is absent.

Figure 14. Fiscal Consequences of Alternative Fiscal and Monetary Policy Mixes 2015–2019.

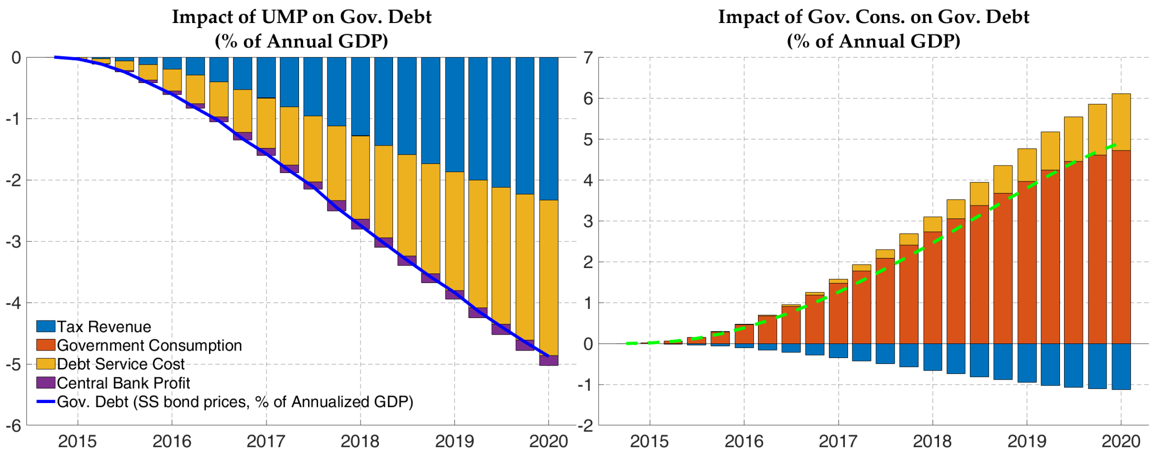
Panel A: Actual and Counterfactuals in Levels



Panel B: Contributions of Alternative Policy Mixes



Panel C: Decomposition of Contributions to Government Debt



Notes: The figure displays tax revenue as a percent of GDP and the Maastricht debt also as a percent of GDP in Sweden from 2014Q4 to 2020Q1 (red solid lines). The other two lines represent counterfactual scenarios: (i) no UMP (neither LSAP nor NIRP, blue dashed lines) and (ii) if no UMP had been implemented, but fiscal policy (government consumption) was used to achieve the same increase in output as UMP. The middle panels (Panel B) show contribution of various policy measures (actual minus scenario without policy measure) to tax revenues and government debt. Panel C provides a decomposition of the lines shown in the right-hand chart of Panel B, breaking down their individual components for further analysis.

But there are also other important differences. For instance, we see that the increase in tax revenues under fiscal stimulus is smaller than how much Riksbank UMP raises tax revenues (i.e. contribute to lower government debt in the left Panel C). This is the case for two reasons. First, increased government purchases are less effective at stimulating private consumption and, consequently, generates less sales tax revenues than UMP. Second, by exerting less upward pressure on inflation and real wages, fiscal stimulus triggers lower labour income tax revenues than the Riksbank's UMP. Another source to the differences in budgetary costs of alternative policy mixes is debt financing costs. When the central bank undertakes UMP, it will lower short-term policy rates and the term-premium, and increase bond prices. This will lead to a reduction in the consolidated government debt position via lower debt service costs, debt deflation and higher bond prices which we capture with the category "debt financing costs" in the figure. By triggering higher short-term policy rates, increasing term-premiums and lower bond prices, fiscal stimulus leads to higher debt financing costs. And this component contributes slightly more under fiscal stimulus since this policy mix increases debt more.

Following the insights in Correia et al. (2013) and Itskhoki et al. (2014), it is of course conceivable that another fiscal instrument, or mix of instruments, may be associated with notably lower fiscal costs and may lead to higher inflation. Even so, we argued in Section 2.8 that empirical estimates for Sweden suggest that increases in targeted transfers should not have more favourable effects, at least not if used in isolation.

While the upper left panel suggests that the fiscal differences between alternative policy mixes are minor and difficult to spot at any given point in time, there is a stark difference in the consolidated debt paths evolving over time when we cumulate the differences. At face value, our results suggest that it would have been much more costly – and welfare deteriorating – to stimulate the economy with conventional fiscal policy than Riksbank UMPs during this period. This is of course not to say that fiscal infrastructure investments or R&D expenditures would not have been helpful this period. Our model just contains fiscal spending that does not increase the long-term growth path of the economy. Moreover, our analysis cannot be used to say that larger LSAP will be less costly than fiscal stimulus in the future. Had the Riksbank done more LSAP and the term premium been more negative, a faster recovery than materialized during these years could have triggered substantial losses on the central bank's asset purchase portfolio. Still, our analysis makes clear that during this period, the Riksbank UMP led to considerable macroeconomic benefits at a very favorable fiscal costs relative to other means to provide economic stimulus and nudged inflation closer to the nominal anchor.

5. Conclusions

This paper underscores the critical role of the exchange rate channel in transmitting the effects of unconventional monetary policies in small open economies. Our findings highlight that large-scale asset purchases in a small open economy stimulate economic activity and inflation primarily by depreciating the exchange rate. Hence, when the short-term interest rate is at the effective lower bound, quantitative easing can provide meaningful macroeconomic effects even though household and firms are not directly affected by lower term-premiums and long-term yields. Consistent with empirical evidence in Section 2.8, lower yields on long-term domestic bonds and an associated larger supply of short-term central banks reserves weakens the exchange rate. A depreciated exchange rate make import more expensive and enhances export competitiveness of domestic firms and overall leads to higher demand for labor services, resulting in higher wage pressures and domestic core inflation. Thus, a weaker exchange rate supports both output and inflation in a manner that conventional fiscal policy (for example higher government consumption or transfers to households) often cannot replicate.

The prominent role for the exchange rate channel in the transmission of LSAPs carry the implication in our model that LSAP is approximately equally effective if the central banks buys domestic or foreign long-term bonds and pays with short-term domestic reserves. The Riksbank did exclusively the former, while the Swiss National Bank – facing safe haven inflows and due to the shortness of supply of domestic long-term bonds – did the latter. As purchases of foreign long-term bonds paid by issuing short-term central bank reserves is thought of as an FX intervention (but here with the intention of raising inflation rather than merely weakening the exchange rate), our small open economy model implies that LSAP and FX interventions can have very similar effects locally (i.e. when done to generate a similar-sized real exchange rate depreciation).

Given the empirical evidence that policy rates transmit to market rates and interest rates relevant to firms and households in a similar fashion when policy rates are positive (normal situation) and mildly negative (so that financial stability considerations can be ignored), both NIRP and LSAP policies provide economic stimulus and raise inflation in our quantitative model when these tools are adopted for monetary policy purposes. That is, they can have meaningful macroeconomic effects even outside a situation with financial stability concerns. However, as frequent use of LSAPs exposes the central bank balance sheet and may adversely impact bond market pricing by making them less liquid, it seems that central banks should first explore where the ELB is and only thereafter as needed deploy LSAP. The experience of the Swiss national Bank, Swedish Riksbank and the ECB suggests that the ELB on policy rates is notably lower that thought prior to the European debt crisis.

A Swedish case study illustrates these dynamics. Between 2015 and 2019, the Riksbank's unconventional monetary measures – a mix of negative policy rates and large-scale asset purchases – not only provided meaningful macroeconomic stimulus but also improved the consolidated fiscal position by about 5 percent of GDP. Our analysis finds that negative rates and LSAPs contributed about equally to the positive output and inflation gains.

In contrast, a counterfactual scenario relying on fiscal stimulus alone to achieve comparable economic activity implies significantly higher fiscal costs and less favourable inflation outcomes. The stronger currency associated with fiscal measures dilute inflationary pressures, underscoring the exchange rate channel's unique advantage in monetary policy transmission. Hence, our quantitative model suggests that the fiscal benefits of the Riksbank UMP during this period were substantial, and large enough to pay for the subsequent balance sheet losses by the Riksbank in the post-COVID pandemic period by an order of magnitude. It should be noted that our assessment of the benefits of the Riksbank UMP tools is conservative, as we use nonlinear model with convex “banana-shaped” Phillips curves which are less sensitive to policy when there is economic slack and inflation is below target. This nonlinear feature of our model implies that QE is not QT in reverse, as explained in detail by Erceg et al (2024). Moreover, it is important to understand that our assessment of the macroeconomic benefits and fiscal consequences of Riksbank LSAPs include a gradual QT (i.e. a gradual normalization of the long-term asset position). Hence, the favourable impact on output and inflation is not reversed when the assets the Riksbank have bought have gradually matures. However, it is possible that an unexpected increase in long-term and short-term rates (falling bond prices) adversely impact the consolidated fiscal cost of the UMPs down the road (and in fact this happened following the COVID pandemic, but the overall resulting Riksbank balance sheet losses were notably smaller than the gains we document in this study).

Overall, our results suggest that unconventional monetary policy tools such as NIRPs and LSAPs can be useful tools to stimulate economic activity and address persistent below-target inflation in small open economies. Even so, since LSAPs carry risks—particularly for central bank balance sheets—they should be deployed cautiously and apart from episodes with financial stress, they should be reserved for situations when policy rates are expected to be pinned at the ELB for a prolonged period and there is risk for de-anchoring of inflation expectations from target. Adrian et al. (2024) provides an in-depth discussion of how balance benefits and costs of LSAPs against the associated risks to central bank and public sector finances.

We leave several interesting issues for further research. First, given the finding that negative rates appear to be effective, we believe that further work is warranted to reexamine how deeply negative short-term policy rates can be tolerated by the public and thus meaningfully implemented. Second, it would be desirable to examine robustness of results with alternative empirically relevant policy rules – both for the short-term interest rate and LSAPs. Third, we have throughout the paper considered a traditional policy mix with a central bank that is responsible for stabilizing inflation around a target level which is supported by a treasury that eventually stabilizes debt around a desirable level. It would be interesting to extend our work to alternative viable policy mixes as in Leeper (1991), including the possibility of fiscal dominance. Fourth, it would for instance be interesting to extend our model with physical capital (i.e. investment) and features that make it better suited to capture the dynamics during the COVID-pandemic. Fifth, it would also be of interest to explore the consequences and merits of alternative monetary and fiscal policy mixes when some households consume hand-to-mouth, and targeted transfers is a viable instrument to stimulate the economy. Moreover, following the insights in Correia et al. (2013) and Itskhoki et al. (2014), it would also be interesting to study the merits of fiscal policies based on taxes and transfers in our open economy framework. Furthermore, and finally, it would be interesting to extend our framework with Gabaix and Maggiori (2015) FX market frictions and examine the consequences of large-scale asset purchases for small open emerging market economies.

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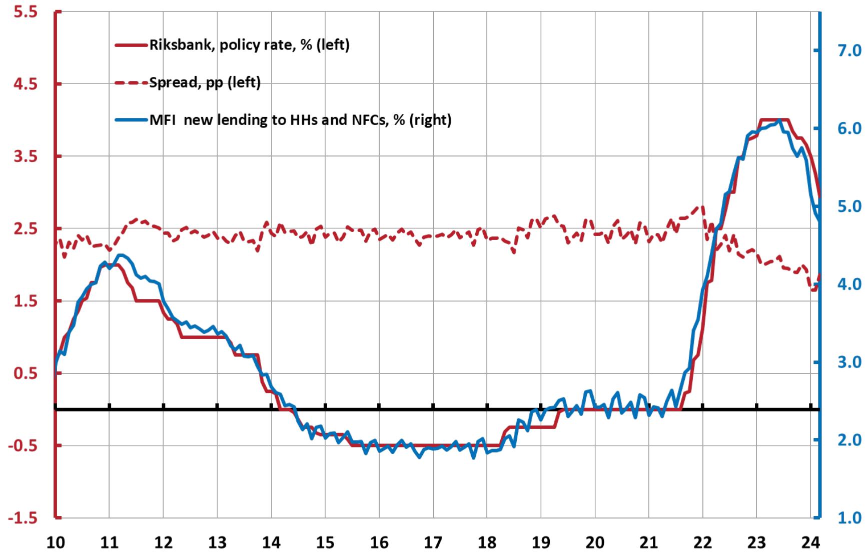
Appendix 1. Pass-Through of Policy Rate Cuts to Lending Rates Under Negative Interest Rates

Eggertsson et al. (2024) examine the bank lending channel under negative nominal policy rates using both empirical and theoretical approaches. Their empirical analysis draws on Swedish data, including daily bank-level lending rates. The study reveals that retail household deposit rates face a lower bound (DLB). Once this bound is reached, they find that further policy rate cuts have a significantly reduced pass-through effect on mortgage lending rates. In our analysis, we broaden the focus beyond mortgage lending rates to consider the general level of interest rates across the entire economy. As shown in Figure 15 below, the pass-through effect on lending rates overall remains unaffected by additional policy rate cuts during the NIRP period.[30]

Figure 15. Swedish Monetary Financial Institutions (MFI) lending rates and central bank policy rate before, during and after NIRP (2015-2019).

Percent



Note New lending refer to agreements that have been entered between the institutes and the customer during the month in question. These include all financial agreements where the terms and conditions that affect the interest are decided on for the first time and other agreements where renegotiations of terms and conditions or direct negotiations concerning existing deposits and loans result in new agreements. The blue line shows "all accounts" which refers to all interest rate fixation periods. As an example, suppose a bank provides loans of two types, at interest rates of 10 and 12 %, respectively, and the respective loan stocks are 120 and 50. The average rate of interest is then obtained as: (120/170)10 + (50/170)12 =10.6 %. Source: Statistics Sweden.

The empirical and theoretical literature on negative interest rate policies (NIRP) examines its impact through multiple channels, including bank profitability, lending, and broader macroeconomic effects. Recent findings suggest both benefits and challenges in using NIRP as a monetary policy tool.

[30] See also Erikson, and Vestin (2019 and 2021).

Appendix 2. Transmission of Conventional Monetary Policy in Sweden

Table 4 presents a comparison of the effects on GDP and inflation of a conventional increase in the policy interest rate in the DSGE model we developed in this paper with findings from other studies that analyze Swedish data. We include studies that use Structural Vector Autoregression (SVAR) models, alongside four Dynamic Stochastic General Equilibrium (DSGE) models used by the Riksbank and the National Institute of Economic Research over the past two decades. To provide broader context, we also incorporate average effects from 57 models from the Macro Model Database based on data from the U.S. and the euro area.

For consistency, we have normalized the effects across studies to reflect the impact of an unexpected one-percentage-point increase in the policy rate. However, readers should note that the persistence of the policy rate response varies slightly between studies, introducing some potential limitations to direct comparisons.

Table 4. Maximum effects of monetary policy on GDP and inflation in Sweden in a selection of research studies

Article	Model	GDP level	Inflation
Jacobson et al. (2001)	VAR	-0,3	-0,3
Villani and Warne (2003)	BVAR	-0,7	-0,3
Adolfson et al. (2008a)	DSGE	-0,5	-0,4
Lindé et al. (2008)	VAR	-0,3	-0,2
Hopkins et al. (2009)	VAR	-0,5	-0,2
Hopkins et al. (2009)	BVAR	-0,1	-0,1
Björnland and Jacobsen (2010)	VAR	-0,7	-0,7
Christiano et al. (2011)	DSGE	-0,4	-0,1
Laséen and Strid (2013)	BVAR	-0,4	-0,4
Di Casola and Iversen (2019)	BVAR	-0,8	-0,3
Corbo and Strid (2020)	DSGE	-0,7	-0,2
Akkaya et al. (2024)	DSGE	-0,4	-0,3
Lyhagen and Shahnazarian (2023)	BVAR	-0,3	-0,2
Almerud, et al. (2024)	Proxy VAR	-2,0	-1,0
Median		-0,5	-0,3
Laséen et al. (2022)	57 DSGE Models	-0,8	-0,5
This study	DSGE	-0,4	-0,3

Source: Adapted from Berggren et al. (2024).

In Swedish studies, the median peak effects on GDP and inflation are -0.5 percent and -0.2 percentage points, respectively, typically occurring a little over a year after the rate change. For studies using VAR models, these effects are -0.4 percent and -0.3 percentage points. Notably, the peak effects in the Swedish studies align closely with those found in U.S. and euro area data models, as well as with estimates from the current models employed by the Riksbank (MAJA) and the National Institute of Economic Research (SELMA). Notably, the effects we observe in our own study are highly consistent with these findings.

Appendix 3. Transmission of Exchange Rates to Net Exports and Inflation in Sweden

In this appendix, we use local projection (LP) methods to estimate the effect of changes in Sweden's real effective exchange rate (REER) on net exports relative to GDP (NX) and CPIF inflation. CPIF is measure of prices calculated for fixed nominal short-term interest rate, in an attempt to strip out the impact of the interest rate component of monetary policy on housing prices in an environment in which the bulk of households have mortgage loans based on variable rates. The LP approach estimates the response of net exports and inflation to changes in the real effective exchange rate using the following equation:

$$Y_{t+h} = \beta_h \Delta log(REER)_t + \Gamma_h X_t + \Psi_h D_t + \varepsilon_{t+h}, \tag{10}$$

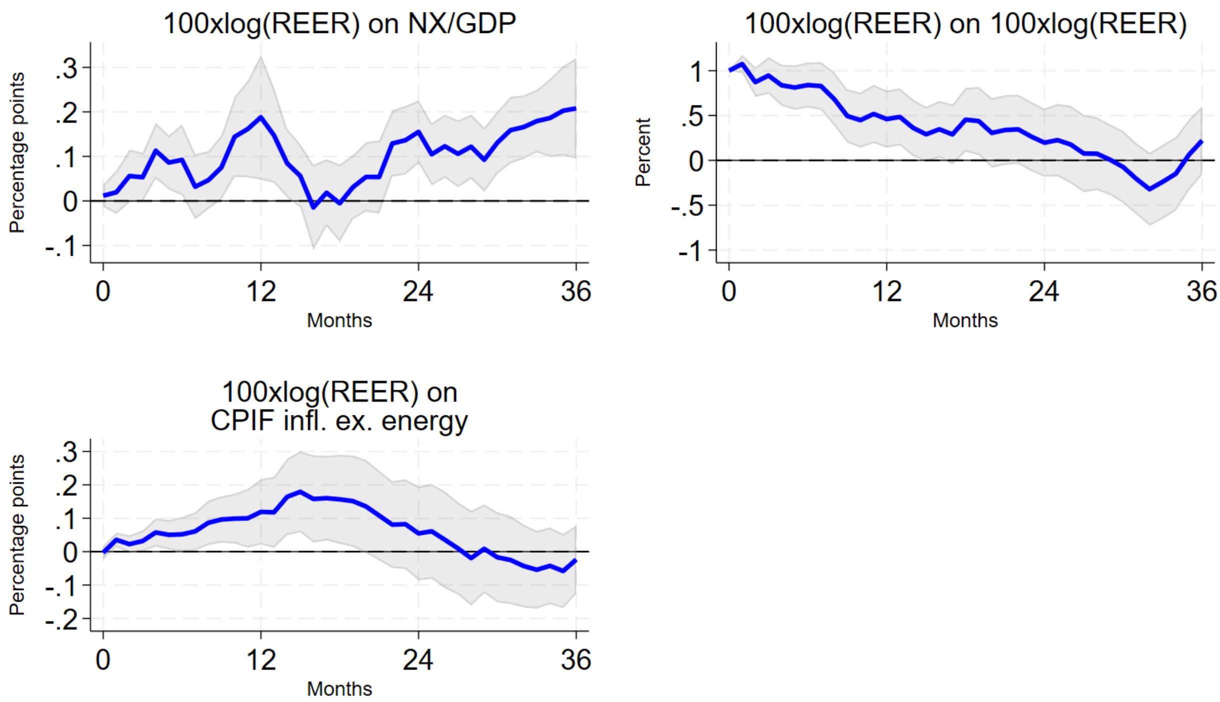
where Y_{t+h} is either net exports to GDP at time $t + h$, the logarithm of the real effective exchange rate, annual percentage change of the CPIF index (i.e. the four-quarter change in log CPIF price level). $\Delta log(REER)_t$ is the percentage change in the real effective exchange rate (an increase denotes depreciation), X_t is a vector of macroeconomic control variables including 12 lags of the dependent variable and the real effective exchange rate as well as other control variables (contemporaneous and three lags) such as industrial production in Germany and the United States, the World Geopolitical Risk Index, the 2 year interest rate differential between Germany and Sweden and the spread between 5-Year Treasury Constant Maturity and the 3-Month Treasury Constant Maturity and the DG ECFIN industrial confidence indicator of production expectations for the months ahead. D_t is a vector of dummy variables including 2008-09 crisis, 2010Q3 and the 2020 pandemic. h denotes the projection horizon (ranging from 0 to 36 months). Newey-West HAC standard errors are used to account for heteroskedasticity and autocorrelation up to h months.

The dataset consists of monthly observations from January 2000 to December 2024, extracted from BIS (Bank for International Settlements) for real effective exchange rate indices, Macrobond and Eurostat for trade and macroeconomic indicators, Federal Reserve and ECB for interest rates and industrial production and Matteo Iacoviello's geopolitical risk index. Since export and imports are only available as monthly data for goods, we use quarterly data from the balance of payment statistics which also include services, and interpolate from quarterly data to monthly frequency using the Denton method. The results are robust to alternative definitions of net exports (only goods using monthly data vs. goods and services).

Figure 16 shows that in response to a 1 percentage point depreciation in the real effective exchange rate, net export, as a share of GDP, increases with around 0.1 percentage points over a period of three years. The quantitative relationship between the weaker REER and net exports (as share of GDP) is quite similar to the structural macromodel we use (see black lines in Figure 4 and the blue lines in Figure 5 in panels for NX and REER). The lower panels in Figure 16 show the exchange rate pass through to CPIF inflation. A one percent depreciation is associated with around 0,1 percentage point higher inflation after approximately one year. These results are very similar to those reported in Almgren and Stoyko (2024).

Finally, we note that the results are robust to alternative exchange rate definitions (narrow vs. broad BIS indices). Varying the number of lags (up to 12 months) does not significantly change the estimated impulse responses. Moreover, when we instrument the level of the Swedish real exchange rate with the U.S. broad effective real exchange rate – exploiting the idea that movements in the US REER should not be affected by Swedish developments but be correlated with the Swedish REER – we also obtain very similar results to those in Figure 16.[31]

Figure 16. Response of Net Export (% of GDP), the Real Effective Exchange Rate (REER), and CPIF inflation to a REER shock.



Note. Solid lines show the estimated impact of a 1 percentage point real exchange rate (REER) shock on net exports (NX/GDP), the REER, CPIF inflation excluding energy (12-month change). Shaded areas represent 90 percent confidence bands.

[31] Furthermore, and finally, we also obtain similar results to those reported in Figure 16 by estimating the impulse-responses using a VAR-model where the real exchange rate shock is identified with a standard Cholesky factorization with the real exchange rate ordered first in the VAR.

Appendix 4. Transmission of Asset Purchases to the Exchange Rate in Sweden

In this appendix we use a SVAR model identified using an external instrument to investigate the effect of asset purchase announcements on the real exchange rate, long term yields and the Riksbank's holdings of government bonds. We use the method described in Bu, Rogers and Wu (2021) to estimate a monetary policy shock specifically derived from longer term zero-coupon bonds as the external instrument in the SVAR. We elaborate on this method in the last section in this appendix.

Our monetary policy shock series spans both conventional and unconventional policy periods, remains largely unpredictable, and exhibits no significant central bank information effect. We compute the series from January 2001 to December 2019 but set the instrument to zero prior to 2015 to exclusively focus on monetary policy announcements which moved longer term yields during the UMP period. In addition, we incorporate the Riksbank's holdings of government bonds into the SVAR to examine whether the shock in addition to lower long-term bond yields also increases CB asset holdings. To account for the potential weak correlation of the external instrument, we apply the method proposed by Montiel Olea, Stock, and Watson (2021) (MOSW) to construct confidence sets for the impulse responses.

We estimate a monthly SVAR model in which we include the five-year zero coupon government bond yield, the log of the Statistics Sweden's monthly GDP indicator, the log of the CPIF index, the log of the BIS real effective exchange rate index (a decrease indicates a depreciation), Riksbank holdings of government bonds as a share of annualized 2014Q4 GDP in current prices, the log of the OMX stock price index. The VAR is estimated using 3 lags and a constant term. The dataset consists of observations from January 2001 to December 2019.

The MOSW weak instrument statistic $\xi_1 = 4.5$ is below the Staiger-Stock value of 10, suggesting that the instrument is weak. However, because the 5% critical value is 3.84, the 95% Anderson–Rubin weak-instrument confidence sets for the impulse response coefficients are bounded intervals.

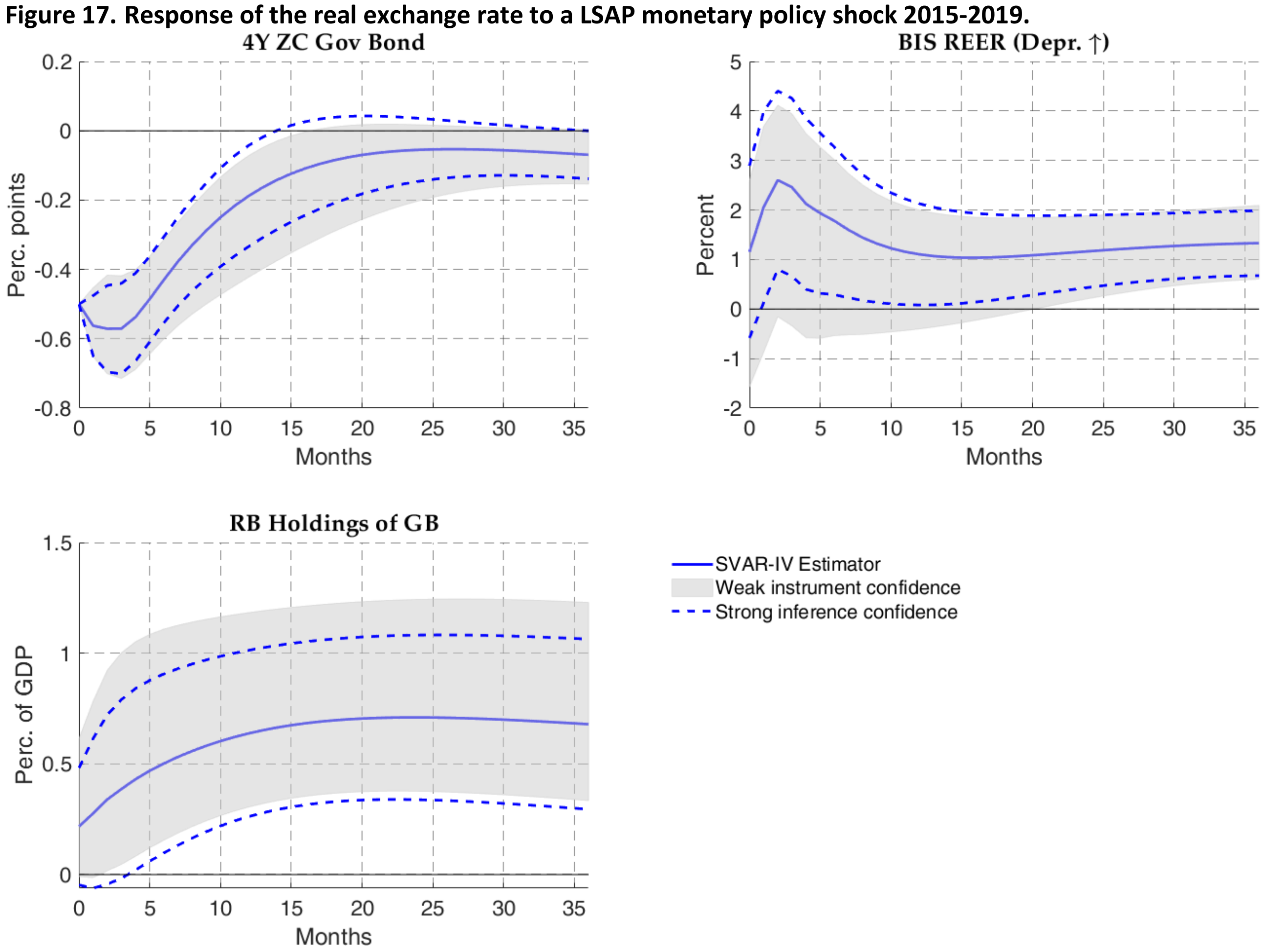
Figure 17 shows the estimated impulse response coefficients from a shock to the LSAP instrument and corresponding confidence sets scaled to lower the five-year yield by -0.5 percentage point. The 68% weak-instrument robust confidence sets (shaded gray area) essentially coincide with the strong instrument intervals (dashed lines).[32] A LSAP policy shock lowers long term bond yields and increases the asset holdings of the Riksbank. The real exchange rate initially falls with over 2 percent and experiences a sustained deprecation with over one percent.

[32] The 95% confidence sets suggest considerably more uncertainty than their strong instrument counterparts (not shown). This is due to the relatively short horizon of UMP between 2015-2019.

Conventional short-term interest policy shocks were small and irregular during the 2015–2019 period, making inference weak when using instruments such as intraday tick data for the 1-month SEK overnight index swap (STINA) rates in the SVAR framework. Hence, we also include the Anderson–Rubin weak-instrument confidence sets in Figure 18 which presents the impulses for this shock. Notably, the estimated impulse response coefficients for this shock do not significantly impact the Riksbank's holdings of government bonds, as expected.

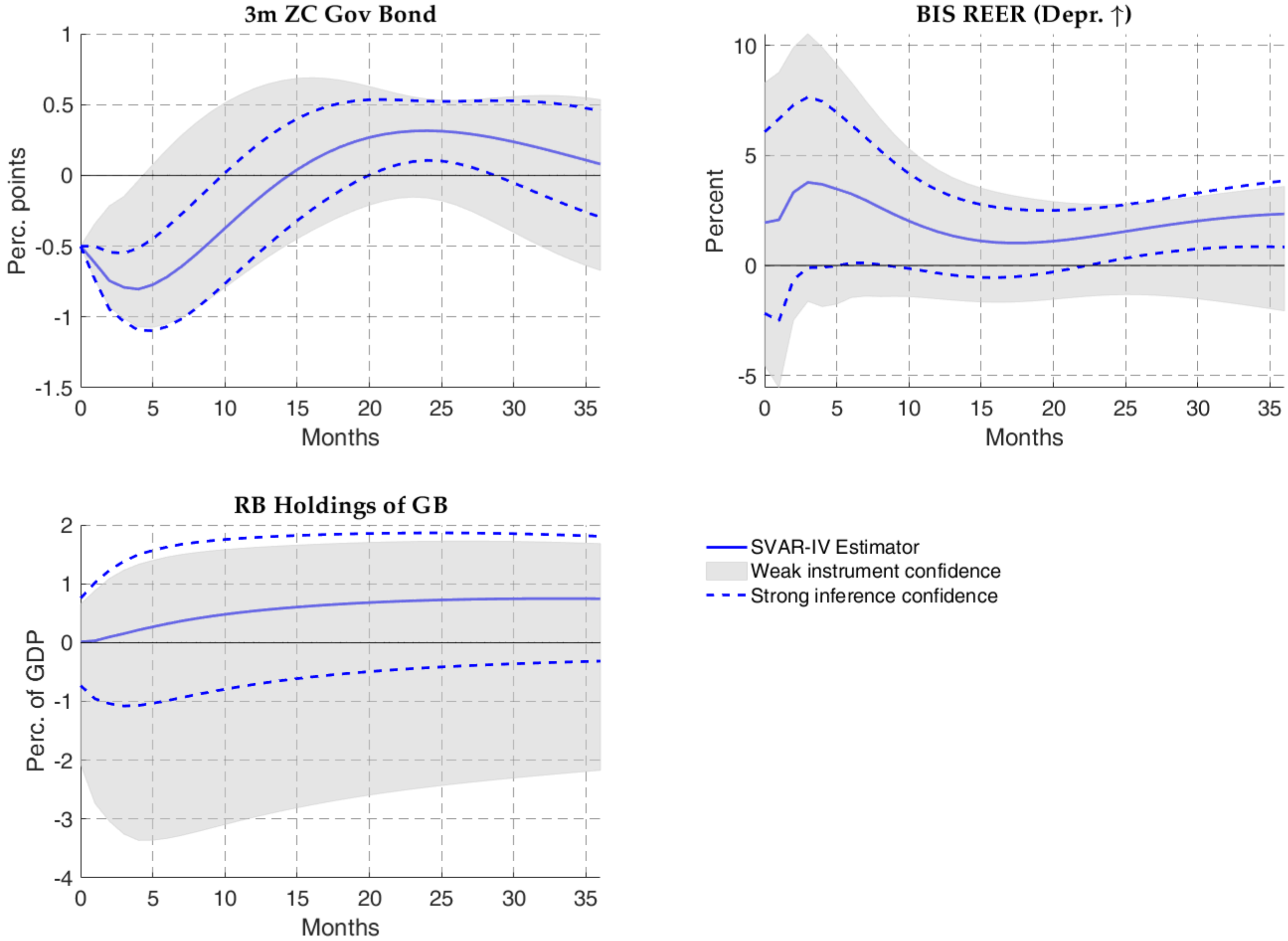
These results reinforce the conclusions drawn from the DSGE model. Asset purchase shocks influence long-term interest rates, weaken the exchange rate, and stimulate inflation and economic activity (not shown) to a similar extent as observed in the DSGE model. Short-term policy rate shocks weakens the exchange rate but does not trigger any changes in the central bank's holdings of long-term assets.

Figure 17. Response of the real exchange rate to a LSAP monetary policy shock 2015-2019.



Note. Solid lines show the estimated impact of a -0.5-percentage point LSAP monetary policy shock during 2015-2019 on the real exchange rate and the Riksbank holdings of government bonds. Shaded areas represent 68 percent weak instrument robust confidence bands.

Figure 18. Response of the real exchange rate to a conventional short-term policy rate shock 2015-2019.



Note. Solid lines show the estimated impact of a -0.5-percentage point conventional monetary policy shock during 2015-2019 on the real exchange rate and the Riksbank holdings of government bonds. Shaded areas represent 68 percent weak instrument robust confidence bands.

The methodology used to estimate the LSAP monetary policy instruments

The methodology for estimating our LSAP monetary policy instruments follows the approach outlined in Bu, Rogers, and Wu (2021). In this section, we explain the approach. We assume that the monetary policy shock e_t is unobservable. We further assume that the observable changes in Swedish government bond yields around the Riksbank's monetary policy decisions are driven by the monetary policy shock and a non-monetary policy shock as follows:

$$\Delta R_{i,t} = \alpha_i + \beta_i e_t + \epsilon_{i,t,} \quad i = 3m, 6m, .., 5Y; \; t = 1, 2, \ldots, T;$$

where $\Delta R_{i,t}$ is the observable change in a zero-coupon government bond with maturity i, at each monetary policy meeting between January 2001 and September 2023 (we exclude dates where other central banks also announce decisions). $\epsilon_{i,t,}$ are all other factors not related to monetary policy. The aim is to estimate e_t which is the variable that we will use as an instrument in the SVAR model that we are estimating. BRW use the Fama-MacBeth two-step procedure to extract e_t from the common component of $\Delta R_{i,t}$.

In a first step, the method involves estimating the sensitivity of the observable changes in Swedish government bond yields to monetary policy changes (β_i) using time series regressions. To do so, we normalise the shock so that it has a one-to-one relationship with the change in a one-year government bond rate ($\beta_1 = 1$). We can then rewrite the above equation as follows

$$\Delta R_{i,t} = \alpha_i + \beta_i\left(\Delta R_{1,t} - \alpha_1 - \epsilon_{1,t}\right) + \epsilon_{i,t,} = \theta_i + \beta_i \Delta R_{1,t} + \vartheta_{i,t}.$$

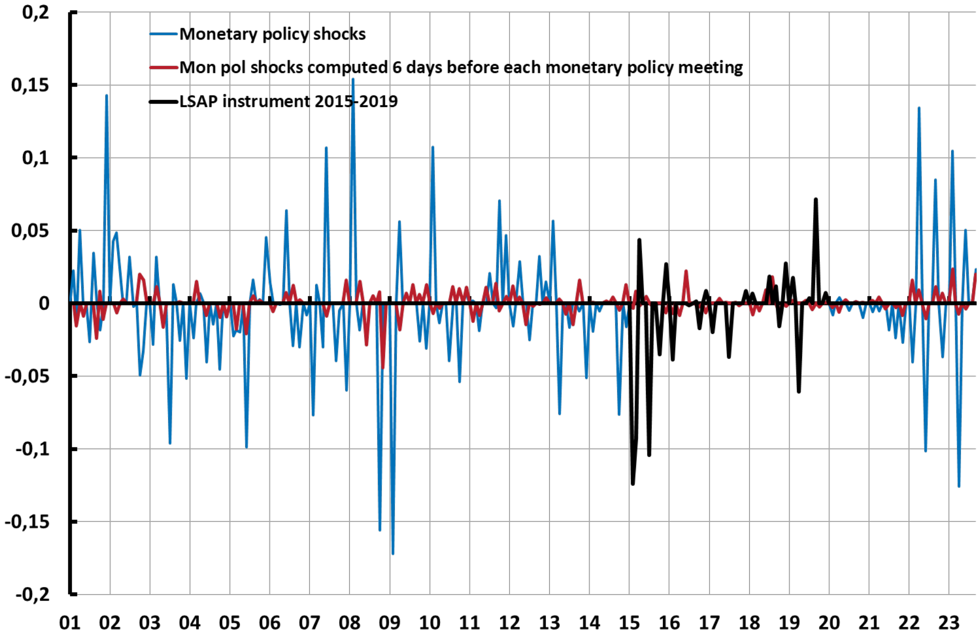
Since the residual $\vartheta_{i,t}$ is correlated with the independent variable in the regression ($\Delta R_{1,t}$), the regression cannot be estimated using the least squares method. We follow BRW and estimate the regression with a heteroscedasticity-based instrumental variable estimator. The assumption is that the variance of the monetary policy shocks is greater on the days that the Riksbank announces monetary policy decisions but that all other shocks have the same variance on these days. Once the various coefficients $\hat{\beta}_i$ are estimated, the second step is to estimate cross-sectional regressions for each monetary policy announcement date where $\hat{\beta}_i$ is the independent variable and the observable changes in Swedish government bond yields are the dependent variable:

$$\Delta R_{i,t} = \alpha_i + e_t^{aligned} \hat{\beta}_i + v_{i,t}, \ \ t = 1, 2, \dots, T,$$

where $e_t^{aligned}$ is the coefficients in these cross-sectional regressions. Our monetary policy shocks thus capture a common variation in the entire interest rate structure between 3 months and 5 years. The blue line in Chart 2 shows the results of this two-step procedure where we have just normalised the shock to have a one-to-one relationship with the change in a one-year government bond rate. The results become very similar if we normalise with other maturities. The only data requirement is daily observations of zero coupon rates with different maturities.

Figure 19 below shows our measure $e_t^{aligned}$ where *t* represents the days on which the Riksbank has announced monetary policy decisions. For comparison, we have also estimated $e_{t-6}^{aligned}$. In other words, we have estimated the monetary policy shock six days before each decision when no monetary policy news has been announced. A measure of e_t on these days should be very small. The figure shows that this is the case. Our assumption that the variance of the monetary policy shock is greater on days when the Riksbank announces its decisions than on other days appears to be valid.

Figure 19. Comparison of our measure of monetary policy rate changes calculated on days with monetary policy decisions (Monetary policy shocks) with the same measure calculated on days without monetary policy decisions (six days before each decision) and the measure we use as an instrument in the SVAR model.



Note. Sum per month of daily estimated disturbances, January 2001 – September 2023.

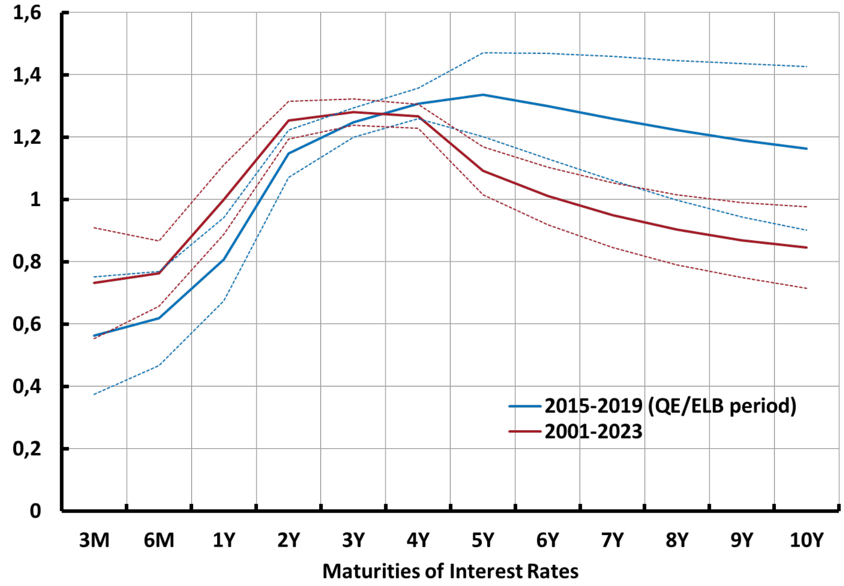
Figure 20 shows how our measure of monetary policy shocks is related to changes in interest rates for different maturities. We estimate the following regression model per maturity i,

$$\Delta R_{i,t} = \alpha_i + \beta_i e_t^{aligned} + \epsilon_{i,t},$$

where $\Delta R_{i,t}$ is the observable change in a zero-coupon government bond with maturity i, at each monetary policy meeting between January 2001 and September 2023 and separately between 2015 and 2019. The figure shows the estimated coefficients β_i for different maturities.

Our estimated monetary policy shocks are significantly related to interest rate changes at all maturities, but mostly to interest rate changes at maturities of between two and four years. The hump-shaped relationship is very similar to that estimated by BRW for the United States and the euro area. Our measure thus captures changes in the entire yield curve and not just changes in short-term government bond yields.

Figure 20. Our measure of monetary policy shocks and the yield curve on days with monetary policy decisions).



Note. The figure shows estimates from a regression of interest rates of different maturities on our new measure of monetary policy rate changes on days with monetary policy decisions. The dashed lines represent a 95-per cent confidence interval. Average effects January 2001 – September 2023.