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Macroeconomic and fiscal impacts of quantitative easing in New Zealand.

Karsten Chipeniuk, Marcin Kolasa, Jesper Lindé, Elvis Lud-vich, and Melanie Quigg

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Reserve Bank of New Zealand
PO Box 2498
Wellington
NEW ZEALAND

www.rbnz.govt.nz

Key findings

- Simulation evidence from a macroeconomic model of large scale asset purchases in New Zealand suggests that the asset purchase programme supported output and inflation during the COVID-19 economic crisis.
- The simulation suggests that asset purchases did not meaningfully contribute to the rise or peak of inflation following the crisis.
- Moreover, the simulation indicates that the asset purchase programme had negligible effects on consolidated government debt. This is due to central bank losses being offset by increased economic activity and associated tax revenues in the model.
- A counterfactual experiment in which moderately negative policy rates replace large scale asset purchases suggests that an effective lower bound of -0.75 percent would have allowed for similar economic outcomes with lower government debt overall.

1 Introduction

Leading up to the Global Financial Crisis (GFC), interest rates had slowly declined across many advanced economies. As a result, the policy rates in these economies were in danger of reaching the effective lower bound (ELB); the point at which the interest rate cannot be decreased further to stimulate the economy. As a result, advanced economy central banks began to explore additional monetary policy (AMP) tools for boosting demand. In response to the GFC, many of these central banks deployed one such tool, quantitative easing, wherein the central bank purchases assets such as bonds or other securities on a secondary market.

Likewise, New Zealand applied a mixture of policies in response to the coronavirus disease 2019 (COVID-19) pandemic and the related economic crisis. On the monetary policy side, this included the implementation of a Large Scale Asset Purchase (LSAP) programme by the Reserve Bank of New Zealand - Te Pūtea Matua (RBNZ).[1] While many advanced economies had implemented quantitative easing policies following the GFC as noted above, this was the first time that such a tool was implemented in New Zealand.

[1] While the New Zealand LSAP programme involved primarily purchasing New Zealand government bonds, such programmes in other jurisdictions have included a wider array of assets. For example, in the United States, quantitative easing has included the purchase of mortgage-backed securities and agency debt of housing-related government sponsored enterprises Fannie Mae, Freddie Mac, and the Federal Home Loan Banks (Federal Reserve Bank of New York, 2025). The European Central Bank's asset purchase programme has included corporate debt, debt issued by recognised agencies, regional and local governments, international organisations and multilateral development banks, asset-backed securities, and covered bonds (European Central Bank, 2025).

Monetary policy actions, both conventional and additional, can have material interactions with the overall fiscal position of the government as a whole, which in New Zealand is reflected in the Crown balance sheet. As such, in response to developments around the GFC and since, there has been heightened focus on the fiscal effects of AMP tools (Office for Budget Responsibility, 2023, Swedish National Audit Office, 2023, and Chadha, 2024). In the New Zealand context, these concerns have led to the development of principles for using AMP tools (Reserve Bank of New Zealand, 2020), and legislation requiring the RBNZ to operate in a financially responsible manner.[2] They also led to the Monetary Policy Committee (MPC) Charter requiring the MPC to consider financial risks associated with monetary policy tools, and explicit consideration of financial risks to the RBNZ and the Crown in the MPC's risk appetite statement.

After inflation increased over 2021, central banks had to raise short-term policy rate to make the policy stance less stimulatory. This created 'mark-to-market' losses for the RBNZ's portfolio of bonds purchased under the LSAP programme. These direct losses on the Reserve Bank balance sheet are easily measurable and have received public scrutiny (See for example RNZ, 2022 and Tibshraeny, 2022). However, the overall net benefits of the LSAP programme, accounting for the range of different channels through which the LSAP programme affects the economy and the fiscal position, are more difficult to measure.

As the LSAP programme was the first quantitative easing deployed in New Zealand, there is limited empirical research on the overall effect of such tools on the New Zealand economy. The RBNZ Review and Assessment of the Formulation and Implementation of Monetary Policy (RAFIMP, Reserve Bank of New Zealand, 2022) outlined the effects and benefits of the LSAP programme, providing some initial estimates of its impact on the New Zealand economy. The RAFIMP noted the considerable difficulty in quantifying the benefits of the LSAP programme, in contrast to the relative ease of measuring the mark-to-market costs. It broadly concluded that COVID-era AMP tools contributed to higher output and inflation during the pandemic.[3] However, the RAFIMP did not quantify the effects of the LSAP programme in a formal modelling framework that internalises the interactions between monetary policy, the fiscal balance sheet and the macroeconomy.

The paper aims to address this gap in our understanding of New Zealand's experience with monetary policy stimulus during the pandemic and its immediate aftermath. First, it aims to measure the impacts of some COVID-19 monetary policies, in particular LSAPs, on the New

[2] Specifically, the Reserve Bank of New Zealand Act 2021 requires the board to "...ensure that the Bank operates in a financially responsible manner and, for this purpose, that it prudently manages its assets and liabilities".

[3] Specifically, the RAFIMP estimates that "...AMP tools had a peak impact on interest rates equivalent to a cut in the OCR of around 90 basis points" and "...with all else equal, the peak impact of a 90 basis point cut in the OCR would: increase the output gap by around 0.6 percentage points, increase annual CPI inflation by around 0.5 percentage points; and reduce the unemployment rate by around 0.3 percentage points" (Chapter 3, p. 58).

Zealand economy and the consolidated fiscal position. Second, it aims to assess the impacts from alternative policies, such as moderately negative interest rates.[4] To do an analysis that examines these issues, we face two key challenges. First, there is relatively little data currently available in the New Zealand context to empirically assess the effects of these policies. A second challenge is the size of the shocks involved and the extreme movements in economic activity, which have not previously been observed in historical data. To address these challenges, we rely on a sophisticated, dynamic stochastic general equilibrium (DSGE) model of the New Zealand economy.

Specifically, we use the model of Erceg et al. (2024), which is a two-country, two-financial asset model with many features in common with conventional structural macroeconomic models used at central banks. In addition to standard short-term bonds, the model includes a separate market for long-term government bonds issued by the fiscal authority, raising the prospect for the central bank to participate in this market (LSAPs). The model also includes features to reflect non-linearities that are important to explain inflation dynamics during periods of volatility, as was observed during the GFC and the COVID-19 pandemic. For example, an ELB constrains declines in the policy interest rate, forward guidance on the policy rate is impeded by households that discount events far in the future, and the supply side features a non-linear Phillips curve which allows inflation to be more responsive to increases, rather than decreases, in demand. The smaller of the two countries in the model is calibrated to the New Zealand economy.

Following Kolasa, Laséen, and Lindé (2025), we simulate the effects of LSAPs taking place over the COVID-19 period and compare with a counterfactual without LSAPs. Our simulation findings suggest that LSAPs supported both inflation and output during the acute period of the COVID-19 crisis, while not dramatically affecting the rise or peak of price rises during the high inflation period that followed. These findings support the conclusions of the RAFIMP, noted above. However, the results suggest that LSAPs did play a role in supporting a more positive output gap than otherwise during the post-COVID period until about the third quarter of 2023. The model results suggest an important transmission mechanism from LSAPs through to reduced long-term rates and hence a suppressed real exchange rate, boosting activity through increased net exports. This increased activity boosts labour tax revenues, and, to an extent, consumption tax revenues, relative to the simulation without LSAPs. As a result, by the end of the simulation horizon, consolidated government debt with LSAPs is very similar to that in the counterfactual case without LSAPs, even though central bank losses on the LSAP portfolio are in line with actual data.

[4] A negative policy rate was not an option for the RBNZ during COVID-19, as the private banking system was not operationally ready for this policy.

We also explore a counterfactual with an AMP tool that the RBNZ did not deploy; using negative interest rates, instead of LSAPs. We also find that with a moderately negative ELB, the policy rate would have still been at this lower bound for an extended period. However, had there been scope to cut policy rates as low as -0.75 percent, close to how low other central banks have cut their policy rates, inflation and activity outcomes would have been very similar to what was observed with LSAPs. However, the results suggest that high inflation may have peaked slightly higher and persisted for slightly longer. Like LSAPs, negative policy rates raise tax revenue, with increasing potency the lower the rates can go (and be effective). They would have resulted in higher government debt during the acute phase of the crisis, but lower debt by the end of the crisis, after the central bank losses are realised. Insofar as negative policy rates stimulate the economy more through domestic consumption (as observed in Kolasa, Laséen, and Lindé, 2025) than the exchange rate channel of LSAPs, these results suggest that policy makers face a number of tradeoffs when choosing between which tools to employ, and in what measure.

This paper contributes to the broader RBNZ research agenda on the economic impacts of the COVID-19 pandemic and policy response in New Zealand. The literature looking at the impact of additional monetary policies in New Zealand is sparse. In a survey of international studies, Kengmana (2021) notes that bond purchasing programmes increased real GDP between 0.5-2.2 percent for every bond purchase worth 10 percent of GDP. Similarly, the peak impact on inflation ranges between 0.5-2.0 percent. In a study considering the impact of the Funding for Lending Programme, Nolan and Tong (2022) found that the programme reduced commercial banks' funding spread by about 15 basis points to the end of 2020, but that pass-through to mortgage rates was slow. However, to our knowledge, this is the first study to estimate the economic and fiscal impacts of LSAPs using a rigorous modelling approach in the New Zealand-specific context.

The remainder of the paper is as follows. Section 2 reviews the relevant international literature within which this work sits. Section 3 outlines the model, focusing on an intuitive description while referring the reader to the benchmark papers for a more formal treatment. Section 4 presents the calibration of the model and impulse response analysis that provides a flavour of how the LSAP programme affects the real economy and the fiscal position. Section 5 describes in detail the simulation exercises that generate counterfactual historical experiments exploring the implications of the non-deployment of LSAPs, and the use of negative interest rates. Section 6 concludes.

2 Related international literature

Almost a decade before the Federal Funds rate troughed during the GFC, Clouse et al. (2000) recognised the possibility that central bank policy rates may reach zero and hit their ELBs in a low inflation environment. The paper considers mechanisms through which purchases of US Treasuries by the Federal Reserve could support economic activity by increasing liquidity, altering expectations, and promoting bank lending when the policy rate is at the ELB. Drawing on the insights from Clouse et al (2000), Bernanke (2002) asserted that "...a central bank, either alone or in cooperation with other parts of the government, retains considerable power to expand aggregate demand and economic activity even when its accustomed policy rate is at zero."

Noting the above developments in the policy arena, Andres, Lopez-Salido, and Nelson (2004) estimate a New Keynesian model featuring imperfect substitutability between long- and short-term financial assets, using US data. The model finds that movements in the relative stocks of assets contribute towards deviations of long-term rates from the forward path of expected interest rates. The results provide empirical support for the existence of a mechanism by which monetary policy can impact long-term rates independently of the compounding effects of its impact on short-term rates, similar to the channels indicated in Clouse et al. (2000) and Bernanke (2002).

The GFC resulted in the Federal Reserve launching its quantitative easing programmes. Chen, Cúrdia, and Ferrero (2012) present a New Keynesian model-based counterfactual experiment exploring what outcomes would have prevailed in the absence of the US LSAP programme and finds that the programme increased output growth by at most a third of a percentage point, with negligible effects on inflation.

Kolasa and Wesolowski (2020) extends the aforementioned work to an open-economy environment, examining the spillover of LSAPs by major economy central banks to small open economies. Calibrating the small economy to Poland and the large economy to a conglomerate of the US, the United Kingdom, and the euro area, the paper finds that LSAPs in the large economy boost domestic demand, but reduce competitiveness and activity in the small economy due to high capital inflows and an appreciation of the real exchange rate.

Motivated by the post-COVID inflation outcomes, Erceg et al. (2024) studies the impacts of central bank long-term bond sales as well as their international spillovers. It finds that, relative to policy rate increases, asset sales generate more adverse international spillovers. These include an inflation-output tradeoff created by a depreciation of the exchange rate in the recipient economy, particularly in emerging market economies with exchange rate pegs.

Adrian et al. (2025) applies the model of Erceg et al. (2024), emphasising the macroeconomic benefits of LSAPs and their tendency to improve the government’s consolidated fiscal position. In particular, the paper notes that LSAPs will tend to decrease the debt-to-GDP ratio due to higher activity boosting tax revenues, debt service costs falling due to lower interest rates, higher bond prices making new debt issuance cheaper, and existing debt being inflated away.

The paper then shows, via simulations based on shocks calibrated to match the 1960-2024 period, that while the central bank often incurs losses due to LSAPs in a shallow liquidity trap, the consolidated fiscal position nonetheless often improves.

Finally, Kolasa, Laséen, and Lindé (2025) examines the macroeconomic and fiscal consequences of LSAPs conducted by the central bank of a small open economy itself, as opposed to spillovers from those in larger economies. Motivated by the Swedish central bank's losses on its LSAP programme leading to a requested capital injection equivalent to about 0.7 percent of 2023 GDP, the paper calibrates a version the model of Erceg et al. (2024) to the Swedish economy to evaluate counterfactuals without LSAPs, without negative interest rates, and without any AMP tools whatsoever.

It finds that additional policies in Sweden did not have a notable impact on output growth and core inflation quarter-by-quarter, but that the cumulative impact and the impact on the exchange rate were significant. Moreover, it finds that additional policies improved the consolidated fiscal position by 5 percent of GDP. It then explores a counterfactual scenario in which government consumption is used to stimulate the economy instead of additional monetary policy measures, finding that this would have entailed higher fiscal costs.

This paper extends the analysis of Kolasa, Laséen, and Lindé (2025) to examine the particular case of the New Zealand economy during the COVID-19 pandemic. In particular, we carefully calibrate the model to match key characteristics of the New Zealand economy. Moreover, we study a particularly volatile period characterised by large economic shocks and a rapid scaling up of the central bank's balance sheet.

3 Modelling framework

We use the model of Erceg et al. (2024), which is closely related to those of Kolasa and Wesolowski (2020), Adrian et al. (2025), and Kolasa, Laséen, and Lindé (2025). This model consists of two countries, a home economy and a foreign economy. It includes many of the features common in the open-economy DSGE literature, such as households that optimise lifetime utility from consumption and labour, firms that optimise profits subject to price rigidities, a government that issues short- and long-term bonds to finance its deficit and a central bank that reacts to deviations of inflation and output growth from their long-run levels. However, the model is also equipped with a number of less standard features that allow for the study of policies such as LSAPs, forward guidance, and fiscal policy.

For example, the model features markets for both short- and long-term government bonds, giving households multiple assets through which to save. To prevent arbitrage from equalising the returns on these assets, the markets for them are segmented, following Andres, Lopez-Salido, and Nelson (2004), Chen, Cúrdia, and Ferrero (2012), and Kiley (2014). In particular, some households are unable to purchase short-term bonds, and only have access to long-term bonds. As noted in Erceg et al. (2024), one interpretation for those households that only hold long-term bonds is that they represent investors such as pension funds who mostly hold long-term safe assets.

Additionally, as in Gabaix (2020), households exhibit bounded rationality in that they expect the economy to return to the steady state after any given shock faster than it in fact will. This feature negates the forward guidance puzzle; the phenomenon that, when the model economy's expectations are formed rationally, announcements about future interest rates have an infeasibly large impact on household behavior (see, for example, Del Negro, Giannoni, and Patterson (2023)).

On the production side, the model features nonlinearities in firms' decisions and the aggregate Phillips curve, due to a demand specification for intermediate inputs that reduces firms' incentive to adjust prices in a weak economic environment while strengthening this incentive when the economy overheats. Preserving nonlinearity is key to capturing these effects, in particular in response to large shocks such as the COVID-19 pandemic. In particular, Harding, Lindé and Trabandt (2022) finds that this feature is key for resolving the 'missing deflation puzzle' during the GFC, the observation that despite the deeply negative shock to economic activity, inflation declined less than expected. Moreover, Harding, Lindé and Trabandt (2023) highlights the importance of the non-linear demand function for high inflation following the COVID-19 pandemic.

Finally, the model features a central bank which is able to release short-term reserves to purchase long-term government bonds, i.e. the model analogue of LSAPs. In doing so, it may realise a profit or a loss on its portfolio, as the prices of the bonds fluctuate. This profit or loss is remitted to the fiscal authority.

A more formal description of the model's fundamentals is provided in Appendix A while the comprehensive details are available in the benchmark paper of Erceg et al. (2024). We deviate from the benchmark model only in the parameterisation of the model to adapt it to the New Zealand case. The parameters of the model are calibrated based on the literature, and in particular, how well the model can match quantitative benchmarks from prior modelling studies on New Zealand. Appendix B describes the calibration strategy in detail.

4 Understanding the transmission mechanism: LSAPs and the dynamics of the real economy and the fiscal balance sheet

Figure 1 shows the response of the model economy to a shock in which the central bank purchases long-term government bonds equal to 1 percent of steady-state annual output. The surprise increase in the demand for long-term government bonds causes their yield to fall, once again eliciting a depreciation of the exchange rate to balance the return on assets in each economy. Similar to what typically follows a conventional expansionary shock to the policy rate, exports, output, and inflation all increase on impact, although the asset purchase shock has a less potent effect on all three.[5] Meanwhile, the consumption of the restricted households who are only able to invest in the long-term asset respond to the lower return by reducing their savings and increasing their consumption. As noted in Kolasa, Laséen, and Lindé (2025), the consumption of unrestricted agents does not respond appreciably to the asset purchase shock, because these agents are able to arbitrage between short- and long-term bonds, and because the policy rate increases in response to increased inflation and output. As a result, the relative consumption of restricted agents increases.

In our calibration of the model (see Appendix B), the adjustment cost parameter that governs the volatility of the holdings of long-term bonds was selected in order to ensure that the output response to an asset purchase shock would not be too large compared to what is found in the literature. In particular, Fabo et al. (2021) surveys both the academic and central bank literature on the effects of LSAPs. Looking at the peak effect of purchases equivalent to 1 percent of GDP, the paper reports that the mean across non-central bank studies is 0.11 percent. As shown in Figure 1, and similar to Kolasa, Laséen, and Lindé (2025), the response of the model economy falls well below this baseline, limiting the likelihood that the results here overestimate the potency of LSAPs.[6]

Turning to the external sector, we see that net exports rise persistently after a slight initial decline. This is driven by a decline in the long-term rate and a resulting depreciation in the real exchange rate, expressed in terms of the quantity of foreign goods that can be purchased

[5] Note that, apart from inflation, the policy rate, LSAPs, and the long-trem rate, variables are displayed as deviations from their steady-state values.

[6] However, it is worth noting that Kengmana (2021) highlights three reasons that we may expect LSAPs to have been less effective in New Zealand during COVID than in other countries. First, long-term interest rates were relatively low for much of the period, limiting scope for further decreases. Second, long-term rates may be less important in New Zealand due to short fixed durations for mortgages and small long-term wholesale funding markets. Third, swap rates are generally more important than government bond yields as benchmark interest rates in New Zealand financial markets.

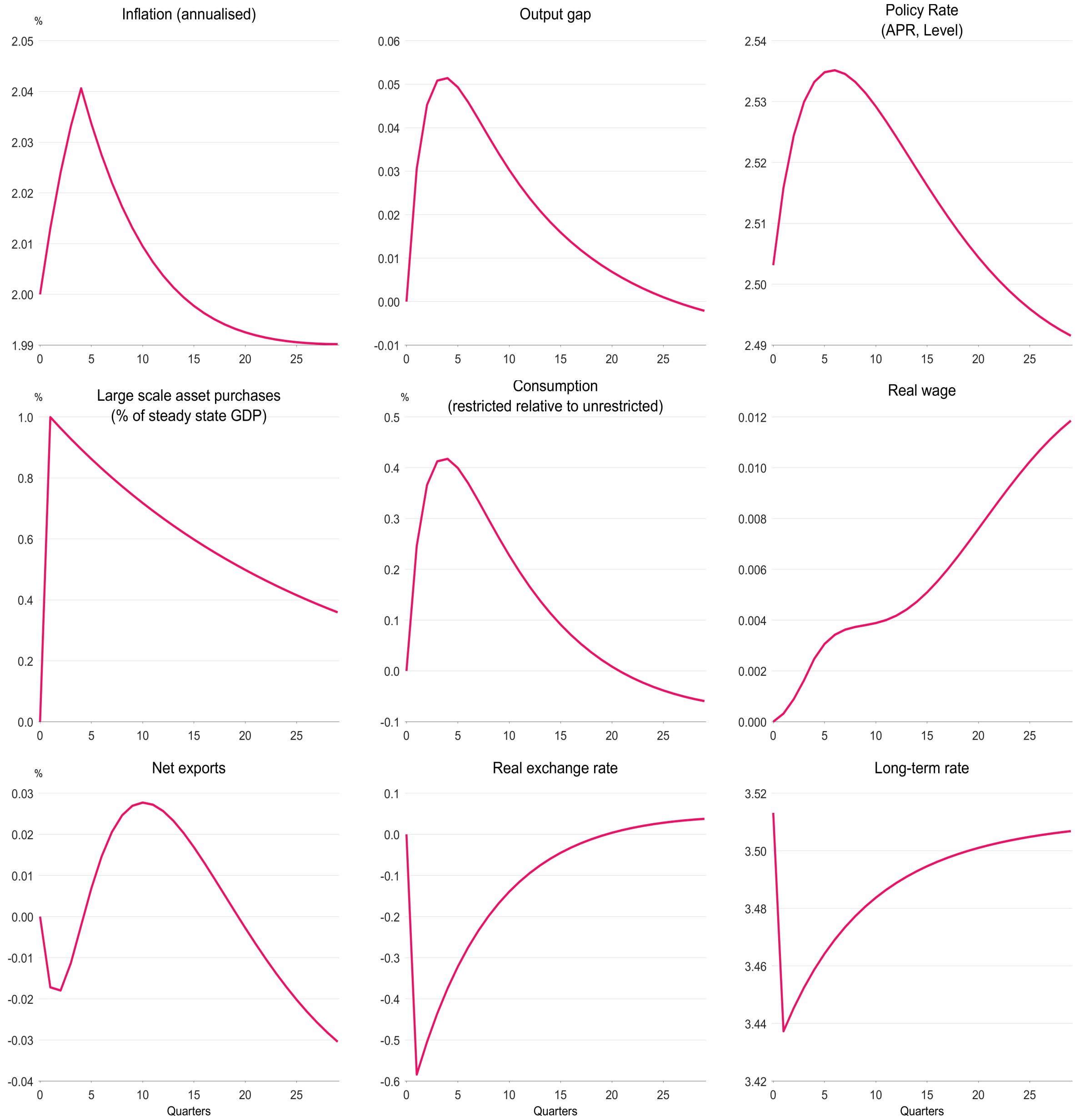

Figure 1: Impulse responses to a central bank asset purchase shock.

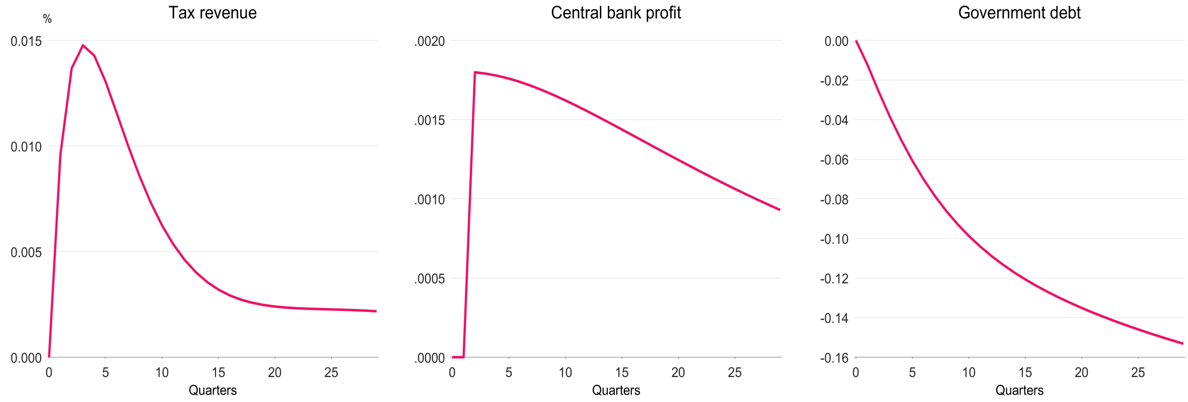

Figure 2: Fiscal responses to a central bank asset purchase shock.

with a unit of domestic goods. Notably, the magnitude of the decrease in the term premium is driven by the stock of asset purchases rather than the flow, so that a less persistent LSAP shock would result in a notably smaller impact.

Finally, we focus on the consolidated fiscal position of the fiscal and monetary authorities. Figure 2 shows the response of tax revenue, central bank profits, and government debt to the LSAP shock, all as a percentage of annualised steady-state GDP. Increased economic activity from LSAPs results in higher consumption and labour income tax revenues for the government. Moreover, the assets purchased by the central bank continue to pay the higher long-term interest rate while being financed by short-term reserves paying the policy rate. While the policy rate rises due to the central bank's endogenous response to inflation and output, and the long-term rate declines due to the additional demand for long-term bonds, the long-term rate remains above the policy rate. This results in a profit for the central bank which is remitted to the fiscal authority. These revenue-increasing effects, along with the lowering of interest payments on long-term bonds, more than offset the increased interest payments on short-term debt, so that the stock of government debt declines following the shock.[7]

However, the presence of long-term assets on the central bank balance sheet alongside short-term liabilities raises the potential risk of a future loss in the event that short-term interest rates in the future exceed current long-term rates. In particular, in the event of further macroeconomic developments resulting in above-target inflation, policy rate increases by the central bank could result in high short-term rates. However, economic agents might expect the situation to normalise and for rates to return to a lower level in the relatively near future. In that case, insofar as the long-term rate reflects an average of short-term rates over the long horizon, it could end up being lower than shorter-term rates.[8] In such a situation, the central bank

[7] More specifically, the response shown here is that of government debt at steady-state bond prices. The market value of this debt increases in the short run due to increased demand pushing up on prices, but declines relative to that in the steady state in the longer run.

[8] Put another way, this could be the case in the event of a negative term premium.

balance sheet characterised by long-term assets and short-term liabilities could be exposed to losses due to this rate differential.

We now turn to examining a situation in which dynamics such as those described in the previous paragraph were in effect, namely the monetary policy response to the COVID-19 pandemic and subsequent economic recovery.

5 Simulating the LSAP programme during COVID-19

The previous section demonstrated the mechanism by which a one-off exogenous asset purchase by the central bank could be both profitable as well as increase sources of government revenue resulting in declining debt, albeit requiring a shift in the risk profile of the central bank's balance sheet. This provides initial support to the notion that, in the event of the central bank making a loss on asset purchases, other sources of revenue could offset this loss. However, asset purchases by the RBNZ during the COVID-19 period differed from this initial exercise in a number of ways.

First, the purchases and subsequent unwind took place in an environment with additional shocks to the macroeconomy. The trigger of the fall in output during COVID-19 was public health related mobility restrictions, unlike in the experiment in the previous section which featured LSAPs as the trigger of the business cycle. Second, LSAPs during COVID-19 were announced in advance, with the purchases themselves only taking place over an extended period following the announcement. Finally, the purchases announced were much larger than the one-time LSAP shock of 1 percent of steady-state GDP used in the previous experiment, with total announcements reaching 33 percent of annual GDP. Since the model features nonlinear characteristics, the responses of optimising agents to large shocks may differ significantly from a simple scaling up of their responses to smaller shocks. Hence, while the previous exercise helps us understand how a surprise increase in LSAPs transmits, it is important to design the policy experiment in the model appropriately to mimic the situation faced by the New Zealand economy during the episode.

5.1 Macroeconomic policy during the pandemic

The RBNZ's asset purchases during the pandemic were conducted in response to significant macroeconomic developments. Throughout the entire period, a variety of restrictions on economic activity were in place to limit the spread of the virus in the event that it should reemerge in the country. These included the closure of the international border, a two-month nationwide lockdown to contain the initial spread of the virus, two additional lockdowns in the Auckland region, and a second nationwide lockdown to contain a more contagious variant of the virus. Towards the end of these public health-related restrictions, the New Zealand economy was also exposed to supply chain disruptions which resulted in high inflation domestically and abroad.

Figure 3 presents the evolution of COVID-era conventional and AMP measures in New Zealand. In response to the public health crisis and the macroeconomic consequences that were initially expected to play out, the RBNZ lowered the OCR to its ELB of 0.25 percent,[9] committing to keep it at that level for one year. In subsequent policy rounds, it continued to publish an OCR track, providing further forward guidance as the situation evolved. Additionally, the RBNZ announced LSAPs of New Zealand government bonds totaling up to 59 billion New Zealand dollars (NZD), and removed its macroprudential restrictions on mortgage lending. Later in the year after the crisis began, the RBNZ also announced its Funding for Lending Programme (FLP), aimed at providing up to NZD 19 billion of low cost funding for private banks which would then be lent onward to individuals and businesses at low interest rates. On the fiscal side, the government established the COVID-19 Response and Recovery Fund (CRRF), totaling NZD 58.4 billion. This fund was allocated to a number of initiatives, such as wage subsidies for employers who experienced revenue declines due to the pandemic, as detailed in Government of New Zealand (2020).

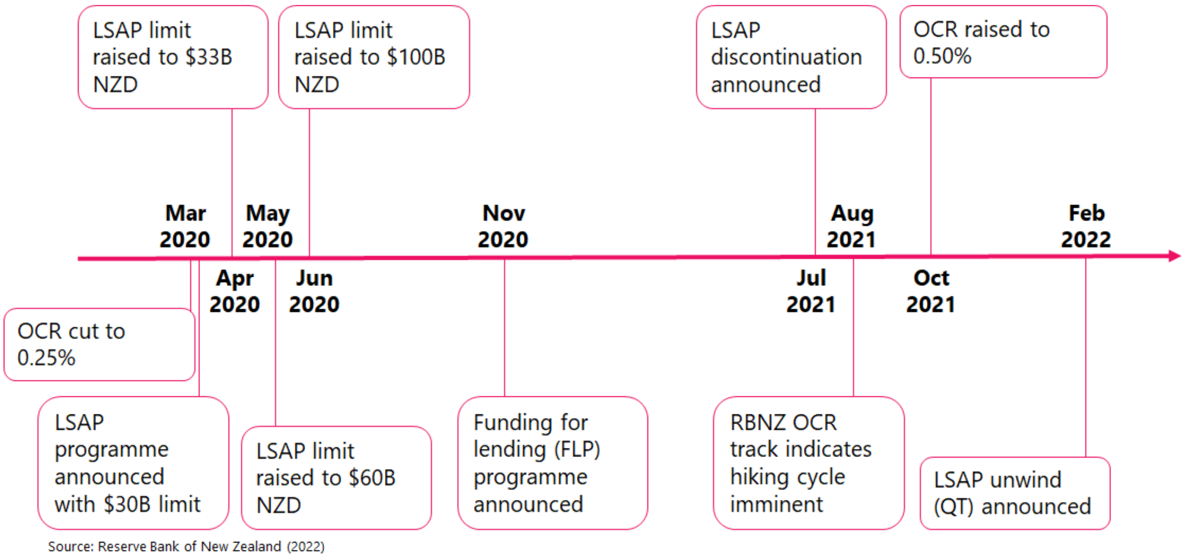

Figure 3: Timeline of COVID-era monetary policies.

5.2 Using demand shocks to mimic COVID-era economic dynamics

In order to capture the economic shocks faced by the economy during this period, we follow the approach of Kolasa, Laséen, and Lindé (2025). This approach is motivated by the idea that

[9]The ELB was considered to be small but positive at this time due to concerns that systems and processes at private banks were not prepared to operate with negative interest rates.

the central bank's policy rate projections are sensible indicators of the size of the positive or negative shocks that are influencing the outlook for the economy as a whole, conditional on other monetary policies being pursued by the central bank. It therefore selects the shocks in the model so that the policy rate track produced by the endogenous response by the model central bank matches as well as possible the actual real-time policy rate projections.

In practice, there are several ways that one could perform the above exercise, given the variety of shocks, present and future, in the model and the various features of the forward rate track. As in Kolasa, Laséen, and Lindé (2025), we adopt a pragmatic approach, selecting a single demand shock in each period as opposed to considering multiple types of shocks. While this approach simplifies the computation of the shock, it does not directly consider supply-side factors which also undoubtedly played a role during the COVID crisis and subsequent reopening. Instead, these shocks can be thought of as capturing the net effect of supply- and demand-side factors during the crisis. Also not considered here are the impacts of fiscal measures taken in response to the pandemic or other demand-side factors. Additionally, choosing a single contemporaneous shock to accompany each projection implies that the rate track simply follows the model's monetary policy rule thereafter, rendering it unable to closely match the entire rate track. We therefore focus on the near term in the projections.

The demand shock we will consider here is an exogenous change in the rate of time preference, i.e. the weights attached to future consumption streams, which implies that the household values future consumption more than current consumption (See Equation 1 in the appendix). Beginning with the economy in the steady state, we initially find a shock which sets the OCR at 1 percent, its level in 2019Q4. Subsequently, we find a shock which puts the OCR at the ELB for one year, the initial period of forward guidance given by the RBNZ in 2020Q1. During the remainder of the acute crisis phase, we find a shock in each quarter such that the duration of the ELB in the model matches that in the RBNZ's forecast policy rate for the corresponding quarter. During the hiking cycle that followed, we find a shock such that the model-implied forecast most closely matches the RBNZ forecasts during the period interest rates were shown to increase. Once the peak in interest rates is reached, we choose the shock to best match the model-implied track to the full RBNZ forecast. For further details regarding this procedure, see Appendix D.

6 Two counterfactual policy experiments

We are interested in conducting two counterfactual experiments. In the first, we examine the economic outcomes in a world in which the RBNZ did not implement the LSAP programme. In the other, we simulate an economy in which the RBNZ was able to use a negative policy rate *in lieu* of the LSAP programme.

6.1 An alternative world without LSAPs

What could have evolved in an alternative world in which the RBNZ did not engage in LSAPs during the COVID-19 economic crisis? In particular, we are interested in how inflation and activity outcomes would have differed, as well as the potential transmission mechanism from asset purchases to these outcomes. Moreover, we are interested in the consequences of the purchases, both for the central bank balance sheet, but more importantly for the fiscal position of the government as a whole.

In order to conduct this counterfactual experiment, we will use the shocks computed in the previous section as indicative of the magnitude of the economic shocks during the crisis. Given these shocks, we perform a simulation of the economy in which the RBNZ makes the announcements as in the previous section, but in which asset purchases are revised to match what was actually bought in each period. After the asset purchases conclude, for simplicity we allow mean reversion in the rule in the central bank's asset holdings to wind the programme down (see Equation 7 in the Appendix A). Additionally, we perform a simulation in which no purchases are announced nor conducted.

The model abstracts from a number of features of the COVID crisis. For example, it only considers monetary policy initiatives, and not specific health policies or fiscal policies such as wage subsidies that were in place. For this reason, the counterfactual time series that are obtained by simulating the model without LSAPs are not directly comparable to those observed in the data. Therefore, in order to remove the impact of the LSAPs from each actual historical time series, we first subtract its simulated analogue in the model with LSAPs. Doing so removes the model-implied impact of the LSAP shocks, but also removes the impact of the calibrated demand shocks. We therefore add back the corresponding time series from the model simulated without LSAPs. In the visualisation of the results, we present the actual data (labelled 'actual') alongside the adjusted counterfactual time series (labelled 'No LSAPs').

Figure 4 displays the actual OCR track in New Zealand during the crisis, as well as the interest rate hiking cycle following the full reopening of the borders and the economy, in the red solid curve. The figure also displays the rate track that the simulation exercise implies without LSAPs in the black dashed line. Both rates decline to the ELB of 0.25 percent in the first quarter of 2020, remaining there until lift-off in the latter half of 2021. They remain approximately equal through most of the hiking cycle, but with the rate without LSAPs ending the simulation period about 19 basis points higher than that with LSAPs. This is due to the additional quanti-

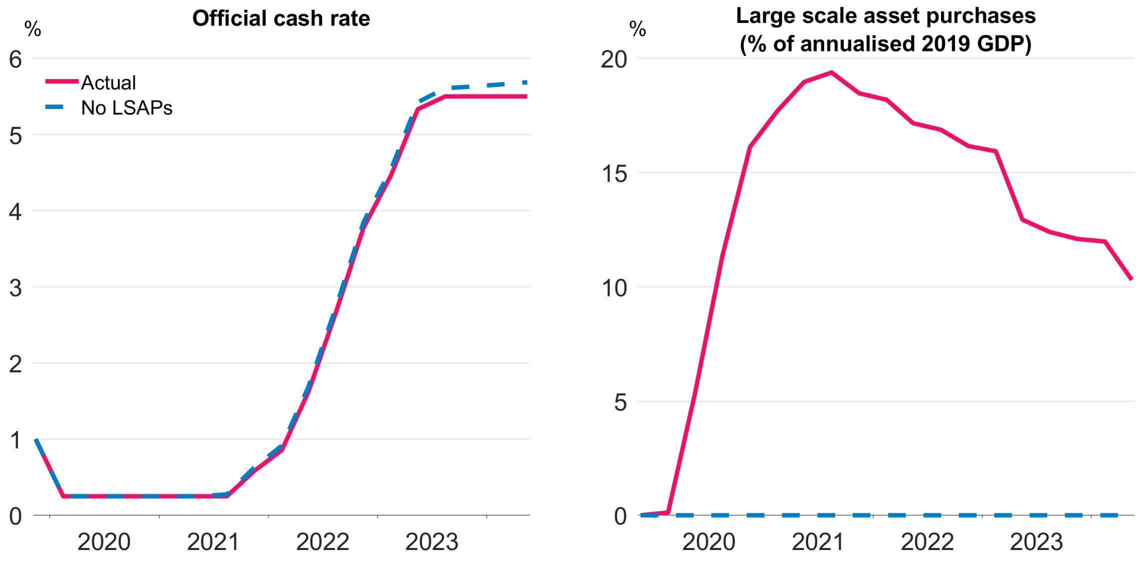

Figure 4: Monetary policy instruments in the no LSAPs counterfactual.

tative tightening effect of the asset holdings being run off the central bank's balance sheet.[10] Figure 4 also displays central bank asset holdings as a percentage of 2019 GDP, rising beginning in the first quarter of 2021 and reaching a peak of 19.4 percent in the middle of 2021, before declining through to the end of the simulation period. Of course, LSAPs are simply zero in the counterfactual.

Next, we examine the implications for consumer price inflation and the output gap in the no-LSAP counterfactual. Figure 5 displays these variables, once again with the actual outturns in the solid curve and simulated outcomes without LSAPs in the dashed curves. Without LSAPs, the model suggests that inflation would have fallen to a trough of 1 percent during the initial crisis period, at the bottom of the RBNZ's target band. Despite LSAPs supporting inflation significantly during the crisis, subsequent shocks were sufficiently large that inflation rises rapidly even without LSAPs. As a result, the OCR moves away from the ELB in the same period with or without LSAPs, reacting endogenously to above-target inflation.

The model further suggests that, although inflation would have been slightly lower without LSAPs throughout the inflationary period, owing to its lower starting point, the eventual peak is essentially identical. This is once again due to the additional tightening due to the LSAP rolloff during the hiking cycle offsetting the stimulatory impact during the crisis. Moreover, at the end of the simulation, the rate of inflation is 0.15 percentage points higher without LSAPs. This suggests that the programme rolling off provides additional monetary tightening, without which high inflation would have been slightly more persistent.

[10]The actual sell-off of long-term assets after the pandemic (Figure 4, right panel) means that output growth during this period was slower than in the counterfactual without LSAPs. Since policy rates respond to growth according to the policy rule, this calls for a slightly higher policy rate path mid-2022 onward without LSAPs.

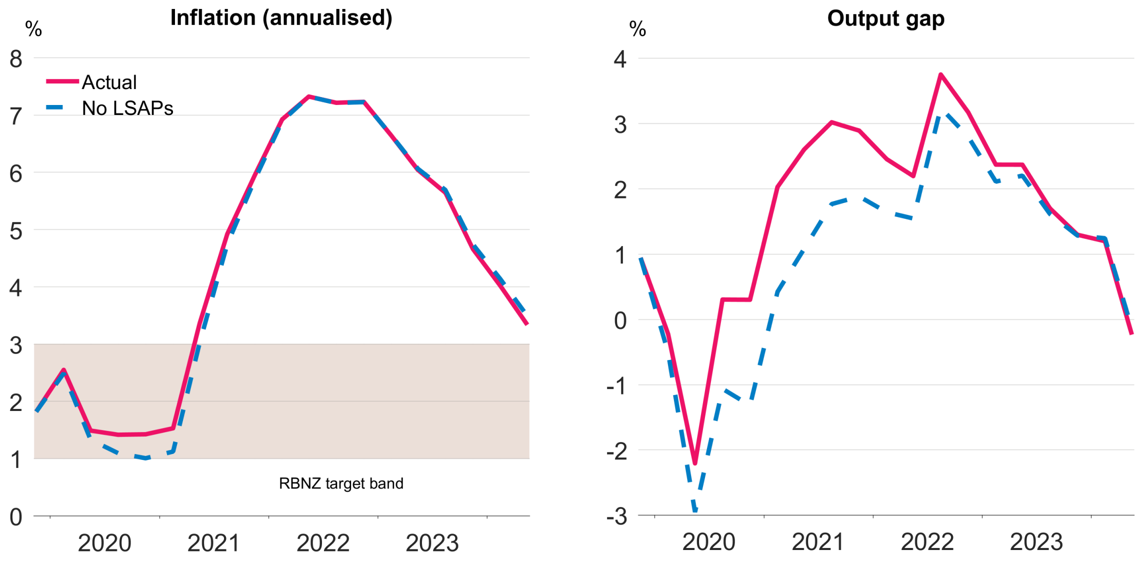

Figure 5: Inflation and the output gap.

The second panel in Figure 5 shows the output gap expressed as a percentage of potential output. We see that the output gap was -2.2 percent in the second quarter of 2020, during the initial nation-wide lockdown in New Zealand. The gap essentially closed in the third and fourth quarters of 2020 and then increased through 2021 and 2022, reaching a peak of about 3.8 percent in the third quarter of 2022, as border closures contributed to labour market tightening and as excess demand remained elevated amid global supply chain impediments.

Without LSAPs, the simulation suggests that the output gap would have been significantly more negative, reaching about -3 percent during the lockdown, and would have only recovered to about -1.1 percent in the latter half of 2020 before becoming positive in the first quarter of 2021.[11] During the subsequent inflationary period, the model suggests that not having the LSAP programme in place would have led to a more stable output gap. In particular, the simulation suggests that while the output gap would have still become positive, it would have been smaller and would have reached a peak of 3.2 percent, 0.6 percentage points tighter than with the LSAP programme. Despite this, the exercise shows that the difference in the output gaps with and without LSAPs would have disappeared by late 2023.

Taken together, these results suggest that the LSAP programme supported the RBNZ's inflation and economic activity objectives through the COVID crisis period. They suggest that the programme did not meaningfully result in inflation reaching a higher peak or the timing of this peak due to the additional tightening provided by the LSAP roll-off. However, they do suggest that the programme contributed to a higher output gap during the subsequent inflationary episode.

[11] Note that, in the model, the policy rate reacts to the growth rate of output rather than the output gap itself, so a larger output gap need not imply a higher cash rate in the later part of the sample.

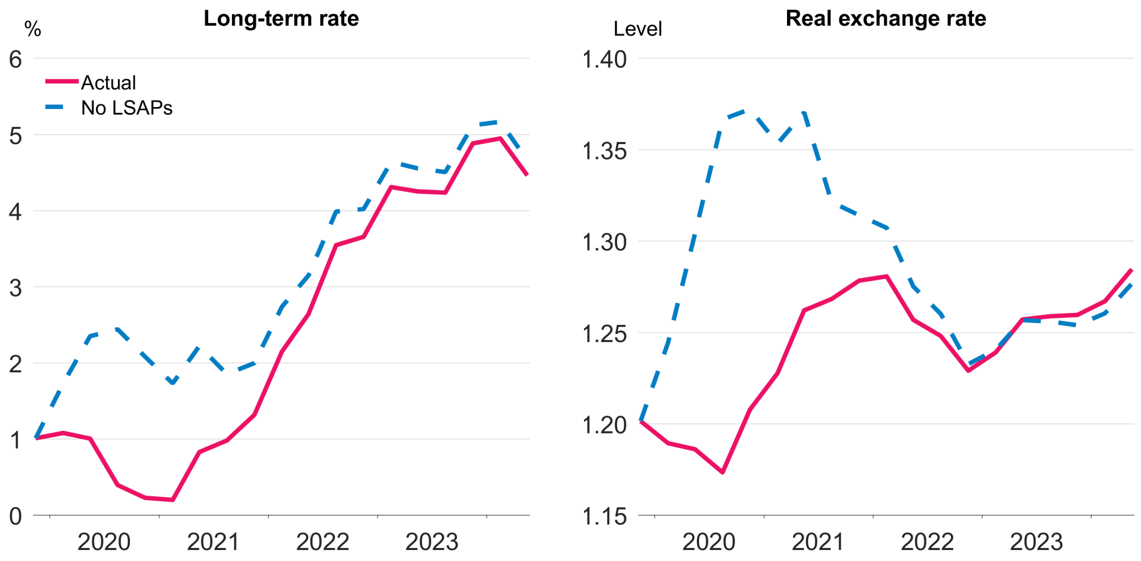

Figure 6: Long-term interest rate and real exchange rate.

To delve deeper into the mechanism leading to the movements in inflation and activity, Figure 6 displays the 5-year New Zealand Government bond yield in the solid line, and the simulation-implied long-term rate in the dashed line. We see that the actual 5-year yield fell from about 1 percent at the start of 2020 to a minimum of 0.2 percent at the start of 2021, reflecting in part the impact of monetary policies by the RBNZ on the New Zealand yield curve. Yields then rise from the first quarter of 2021 to a peak of 4.9 percent in the first quarter of 2024.

The simulation exercise suggests that not conducting asset purchases would have resulted in long-term yields being about 1.4-2 percentage points higher than they were in reality. They would not have begun to rise in a sustained way until the last quarter of 2021, well into the inflationary period. However, they would have remained above the observed rates throughout the simulation period.

The second panel of Figure 6 suggests that LSAPs and the associated impacts on long-term interest rates transmitted to the wider New Zealand economy in part through a strong impact on the exchange rate. In particular, the real exchange rate in reality depreciated from its 2019Q4 value by nearly 2 percent by 2020Q3, whereas without LSAPs the simulation suggests it would have appreciated by about 17 percent.[12] Moreover, these differences are persistent, with the exchange rate without LSAPs only reaching comparable levels to those seen in the data at the end of 2022.

The relatively low exchange rate in reality would have supported demand for New Zealand exports, supporting the economic activity described in the previous figure. However, it is worth

[12] Here the exchange rate is expressed as the amount of the foreign could that can be obtained for a unit of the domestic small open economy good. Hence a larger value represents a stronger exchange rate.

noting an important caveat, namely that the current exercise does not take into account policies being implemented in the foreign economy. These could potentially dampen this channel and mitigate the positive effects of asset purchases. Nonetheless, even if the foreign economy engaged in policy actions which negated the exchange rate channel of LSAPs, the counterfactual of not having done LSAPs would likely have resulted in worse outcomes during the crisis.

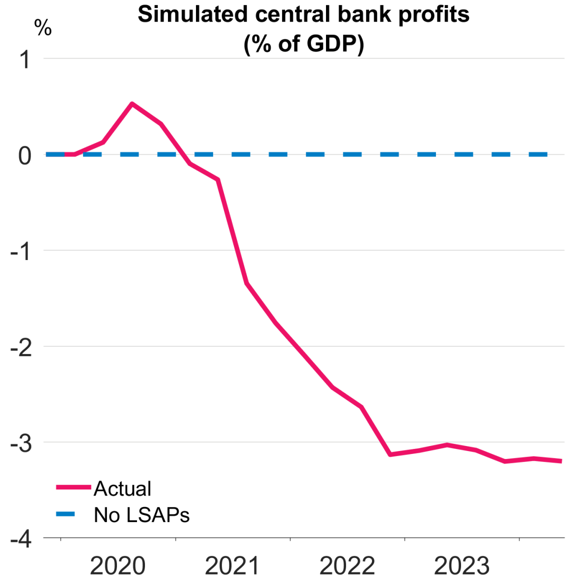

Figure 7: Simulated cumulative central bank profits as a percentage of GDP.

Finally, we consider the fiscal effects of LSAPs, and in particular, their impact on central bank profits, government tax revenue, and consolidated debt. In the case of the former in Figure 7, profits or losses without LSAPs are of course simply zero in the counterfactual simulation. More interesting is the question of whether the model is able to match eventual losses by the RBNZ on its LSAPs. Indeed, the simulated cumulative central bank losses in the model reach a maximum of 3.2 percent of GDP, as shown in Figure 7.[13] This is consistent with the Reserve Bank's current estimates of mark to market losses on the LSAP programme of $10.5 billion - around 3.2 percent of 2020 GDP.

Offsetting these losses, as shown in Figure 8, is higher tax revenue in the actual data relative to the simulation with no LSAPs. In reality, cumulative tax revenue has risen as a percentage of GDP throughout the period under consideration, beginning at 33 percent of GDP and reaching 43 percent of GDP at the end of the period. Meanwhile, the simulation suggests that decreased consumption and labour income tax revenues would have resulted in a slight decline in revenues through 2020Q3. While revenues would have increased thereafter, they would have only reached 41 percent of GDP at the end of the period, remaining below those with central bank asset purchases.

[13] While the endpoint of the central bank loss series is close to that observed in the data, the full time series of central bank losses in the simulation likely differs from that in the data, not shown here.

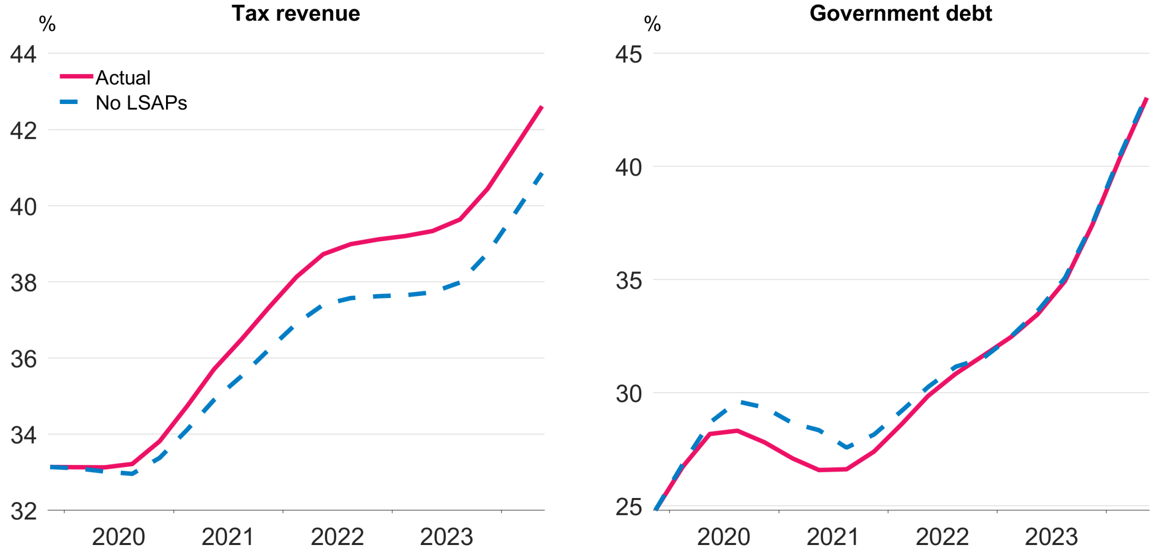

Figure 8: Cumulative tax revenue and government debt.

While the above differences in tax revenue may seem modest compared to the central bank losses reported above, their cumulative impact is not. In particular, the second panel of Figure 8 shows actual gross government debt throughout the simulation period, as well as the counterfactual simulation without asset purchases. The plot suggests that LSAPs and associated tax revenues resulted in lower government debt than in the counterfactual without LSAPs until the end of 2022. Moreover, the results suggest that government debt by the end of the period under consideration was not significantly impacted by the LSAP programme, despite the central bank losses being remitted to the fiscal authority in the model. This provides some evidence that the positive outcomes for inflation and economic activity during the acute part of the crisis, resulting in higher tax revenues and consequently minimal, if any, net fiscal cost.

6.2 An alternative policy instrument: A negative OCR instead of LSAPs

We now consider what outcomes might have prevailed if the RBNZ had been able to set the OCR to a negative value during the COVID crisis. As previously discussed, this was not an option during this period, due to constraints in the private banking system. However, Reserve Bank of New Zealand (2021) noted the progress made by commercial banks in becoming operationally prepared for negative interest rates, and the RBNZ is confident that the New Zealand banking system could operate effectively if the OCR were lowered to or below zero. Hence, since the RBNZ is in a position to consider moderately negative policy rates[14] in a future downturn or crisis, examining this counterfactual may inform on the advantages or disadvantages of this policy.

[14] Negative rates are a potential option despite the existence of cash as an alternative savings vehicle due to the costs of holding large amounts of cash, such as the need to store it securely.

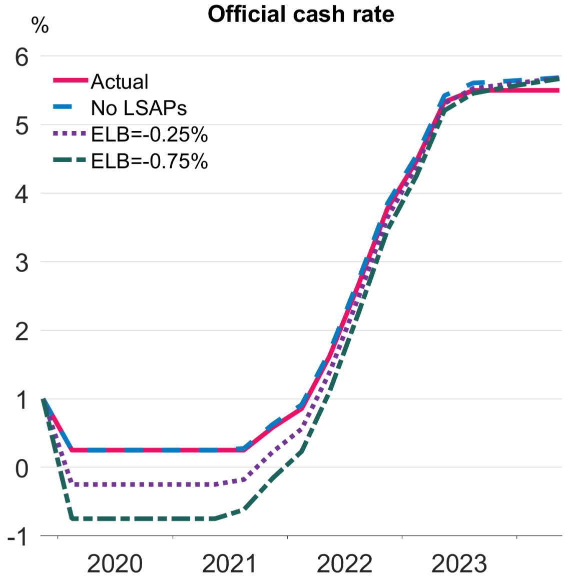

Figure 9: Official cash rate in different scenarios.

We proceed similarly to the previous section. In particular, we simulate the model economy while setting the ELB on interest rates to -0.25 percent, and again while setting it to -0.75 percent. The latter bound is around the limit of what is likely to be feasible.[15] As in the previous section, we remove the marginal impact of LSAPs from the data and add back the marginal impact of negative rates to arrive at the counterfactual series.

Figure 9 shows the resulting tracks for the policy rate. We see that in all scenarios, the model central bank's monetary policy rule takes the rate to the ELB for an extended period. In each of the negative interest rate scenario, interest rates begin to rise a period earlier than they did in reality. This is due to the fact that the model policy rule which the central bank uses when the policy rate is far from the ELB prescribes a policy rate that is above the ELB sooner, when the ELB is lower. However, the policy rate tracks with negative ELBs remain below the actual OCR throughout the hiking period. As shown below, this is despite higher inflation (and higher output in the case of rates dropping as low as -0.75 percent), reflecting the central bank's objective to smooth interest rates. As in the case with no additional policies, the simulated policy rates remain elevated slightly above the observed OCR at the end of the simulations.

Turning to the implications for inflation and output in Figure 10, we see that negative rates with an ELB of -0.75 percent would have performed around as well as the LSAP programme through the crisis period of COVID. Faced with a more moderate lower bound of -0.25 percent, however, inflation and output would not have been supported as well, raising the potential scope for a smaller asset purchase programme in this case. Following the crisis pe-

[15] Cúrdia (2019) notes that the ELB "...is not fully tested and may differ across countries". It further notes that, at the time of publication, Switzerland's reference rate for the one-month London interbank offered rate (LIBOR) had been as low as as -0.75 percent. de Groot and Haas (2020) notes that, as of the time of publication, the Danish and Swiss central banks had set their policy rates at negative 0.75 percent, the European Central Bank and the Swedish central bank had set negative 0.5 percent, and the Bank of Japan had set negative 0.1 percent.

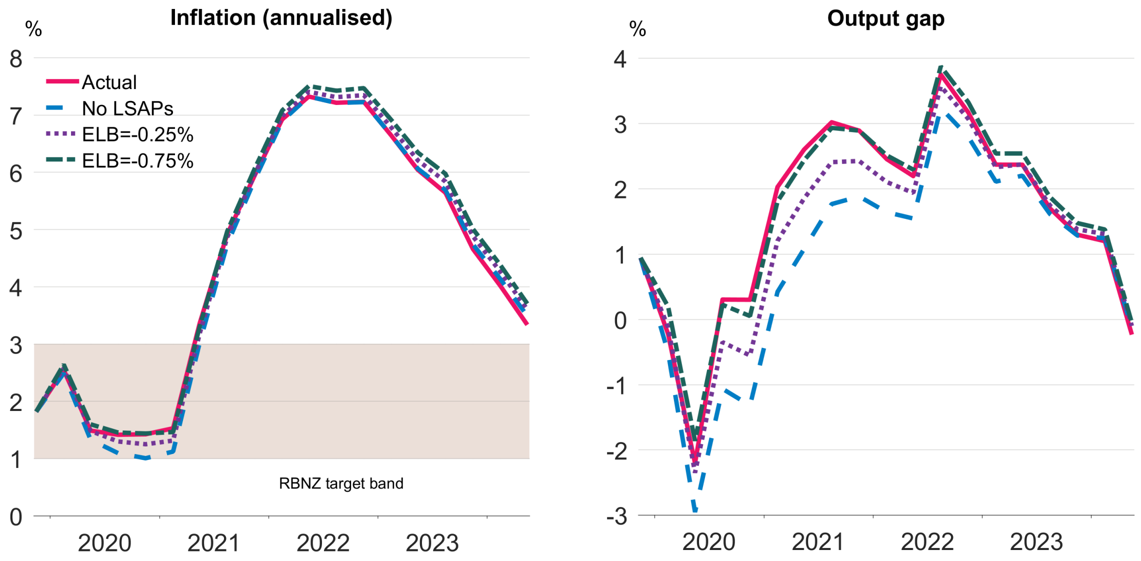

Figure 10: Inflation and the output gap in different scenarios.

riod, however, the simulation suggests that inflation with an ELB of -0.75 percent would have peaked at 7.5 percent rather than 7.3 percent and would have remained elevated relative to what was observed following this peak.

Additionally, it is worth noting that while negative rates with a lower bound of -0.25 percent provide worse outcomes with respect to inflation and output during the crisis than LSAPs or more negative rates, they still do better than the no-additional policy scenario. Moreover, they provide less of an overshoot of inflation than with the ELB of -0.75 percent, and do not allow as large a widening of the output gap following the crisis. This suggests that there are nontrivial considerations for policy makers about the pros and cons of using any given tool, and to what extent, when pursuing their objectives.

Turning to the implications for long-term rates and the exchange rate, in Figure 11, unsurprisingly this channel is much less potent for negative interest rates than it is for LSAPs, which directly push down on long-term yields by increasing the demand for long-term government debt. While decreases in the short-term policy rate do pass through mildly to long-term rates, the long-term rate stays much closer to the scenario with no additional policy than it does to the actual outcomes with LSAPs. Likewise, the usual exchange rate channel of conventional monetary policy remains in effect for negative rates relative to the situation with no additional policy. However, the depreciation caused by negative rates is much less than what was observed with LSAPs.[16]

[16]As noted in Kolasa, Laséen, and Lindé (2025), the UIP condition holds for long-term rates in the model, but not short-term ones.

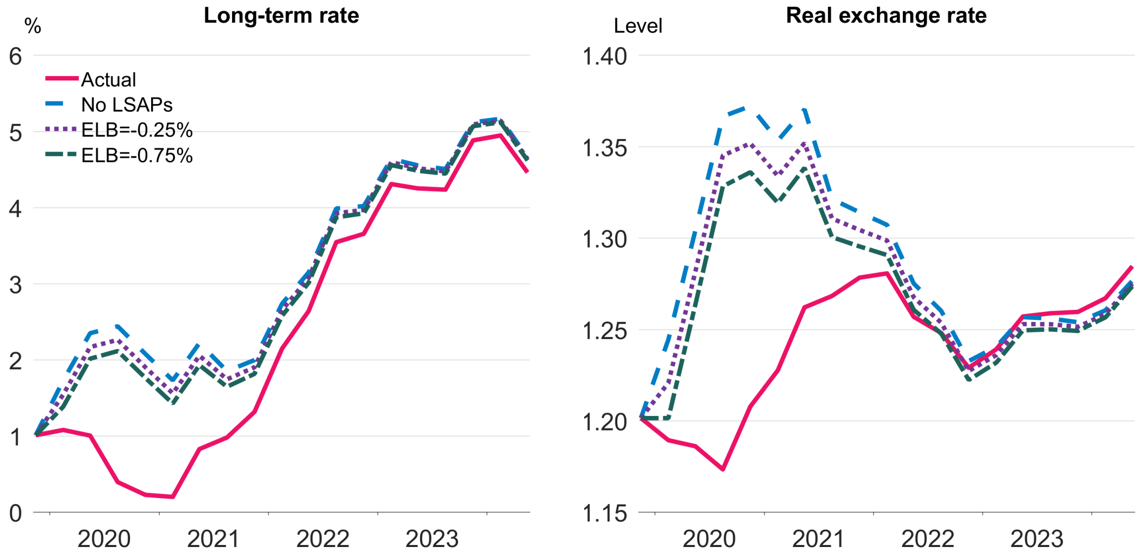

Figure 11: Long-term interest rate and the real exchange rate.

This raises an additional question for policy makers when choosing between various tools. Figure 13 in Appendix C presents the cyclical dynamics triggered by conventional monetary policy shocks to the OCR. Relative to the case of shocks to LSAPs presented earlier in section 4 we see that policy rate decreases, and by extension, negative policy rates, stimulate a stronger consumption response by domestic agents. To the extent that LSAPs support economic activity by lowering longer term rates and generating a favourable exchange rate for exports from the domestic economy, the policy maker may have a choice of which tool is most appropriate to deploy given the situation at hand.[17]

Finally, considering the implications for the consolidated fiscal position, we note that negative rates, as with the case of no AMP, cannot generate losses for the central bank. However, as shown in the first panel of Figure 12, the extent to which they support tax revenue through increased economic activity is likely to depend on how low they go, and consequently how much activity increases. In particular, we see that the simulation results predict lower tax revenue with an ELB fixed at -0.25 percent, but higher revenue with one fixed at -0.75 percent.

However, even with the more moderate lower bound, lower short-term borrowing costs and the absence of central bank losses outweigh the lower tax revenue for the government. In particular, as seen in the second panel of Figure 12, government debt ends up lower with negative rates with either lower bound. For an ELB of 0.25 percent it is lower by about 1.7 percent of GDP, and for an ELB of -0.75 percent it is lower by about 2.9 percent of GDP. This provides yet another consideration for policy makers when selecting from among these various tools.

[17] It is worth noting however that this model does not feature additional channels through which LSAPs could impact the economy, for example by lowering long-term lending rates available to households and firms through the financial sector.

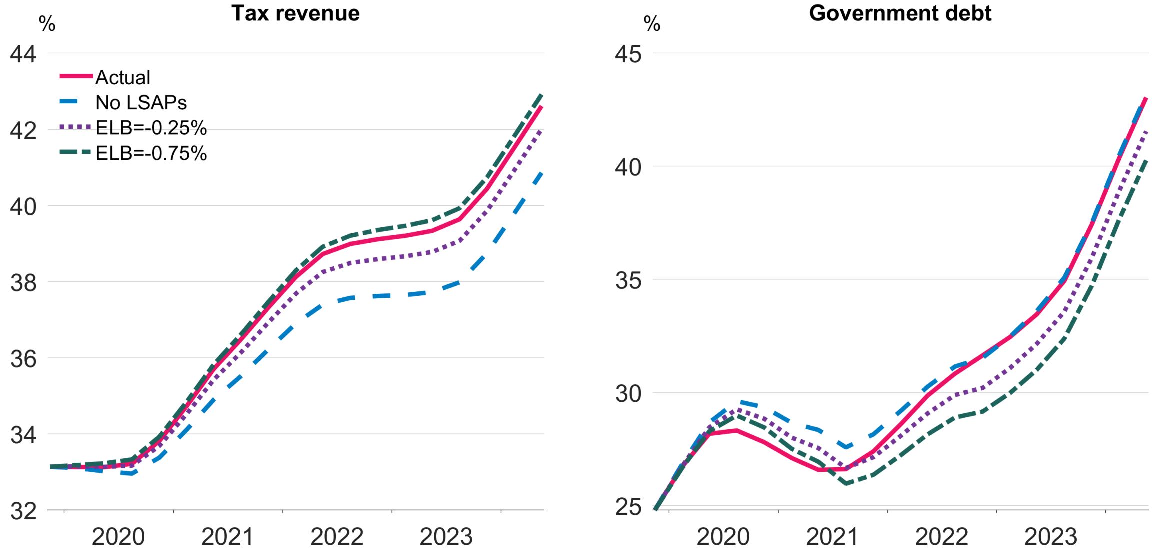

Figure 12: Cumulative tax revenue and government debt.

7 Conclusion

The policy response to the COVID-19 pandemic and related economic crisis involved a number of policies never previously deployed in New Zealand. In this paper, we have considered the impact that some of these policies may have had, specifically the RBNZ's LSAP programme, forward guidance, and a policy rate constrained by the lower bound of 0.25 percent. In particular, we have examined what effect they may have had on inflation and economic activity during the pandemic and the high inflation period that followed, as well as how they may have impacted government debt consolidated across the entire public sector given the losses that were realised on the RBNZ's portfolio. We have also considered what the outcomes may have been had the RBNZ been able to pursue a policy with mildly negative short-term interest rates; this was not a possibility during the COVID period due to the lack of operational readiness in the wider financial sector.

Our model suggests that LSAPs supported inflation and output during the crisis period of COVID-19, while not contributing materially to the subsequent rise or peak in inflation. However, the evidence also suggests that they may have contributed to a higher output gap following the crisis, due to their continuing effect on long-term rates and consequently the exchange rate. Finally, the modelling results imply that losses realised on the RBNZ's asset purchase programme may have been largely offset by the increased tax revenue they generated and lower interest payments on government debt, resulting in no meaningful long-run difference in consolidated government debt. This suggests that the positive effects of the policies during the crisis period were attained without any significant fiscal cost for the consolidated government balance sheet.

Turning to negative policy rates, we found that if the ELB had been -0.75 percent during COVID, then further policy rate decreases could have produced inflation and output outcomes very similar to the case of LSAPs. We found that a more moderate ELB of -0.25 percent would have resulted in more moderate support for the economy during the crisis, with a milder increase in the output gap following the crisis. While we found that inflation may have peaked higher and persisted more under this policy, the difference is minor. Additionally, while tax revenues may have been higher or lower with negative rates than with LSAPs, depending on the ELB assumed, the results suggest that government debt would have been lower by the end of the simulations. This is in part due to the lack of central bank losses.

The results suggest a number of tradeoffs for policy-makers when choosing between various policies and mixes of negative policy rates and LSAPs. The simulation results suggest that LSAPs stimulate the economy by lowering the long-term rate and hence the exchange rate, increasing the competitiveness of domestic exports as well as their New Zealand dollar value. It also suggests that negative rates play more of a role in stimulating domestic rather than export demand, and that negative rates have positive fiscal implications relative to LSAPs. Hence policy makers may select a different policy mix depending on the mechanism through which they hope to affect the economy, as well as depending on the fiscal risk characteristics of the tools.

While this paper is an important step towards understanding the impact of COVID-era additional monetary policies on the New Zealand economy, a number of additional questions remain. While we have looked at some of the policies deployed during this period, further work to better understand the impact of the RBNZ's Funding for Lending Programme or removal of macroprudential policies is welcome. Further understanding the impacts of the COVID-19 Response and Recovery Fund to stabilising the economy would also help to clarify how fiscal policy can contribute when the policy rate is at the ELB. Finally, the current analysis has focused on a single demand-side driver of the economy, whereas there were likely multiple demand-side factors during the crisis and supply-side elements are known to have been important later in the crisis. Future work could explore the robustness of these results along this dimension. Exploring these topics, and others, will help the RBNZ to maintain readiness for potential future crises and better understand the likely impacts of the policy tools that are available.

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A Model

Here we describe the fundamentals of the model in more detail, focusing on the objective functions and constraints that the economic agents face. We refer to Erceg et al. (2024) for more information on the finer details.

Households There are two groups of households, one group unrestricted in their access to financial markets, the other being restricted to holding long-term bonds. In every period t, households in the economy choose consumption c_t, labour hours n_t, and bond holdings to maximise

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \exp\left(\varepsilon_t^d\right) u(c_t - \varkappa C_{t-1}, n_t), \tag{1}$$

where we have suppressed notation indicating the type of the household for simplicity. In this expression, u is the period utility which increases with higher consumption and decreases in labour hours.[18] The parameter $\varkappa \in [0, 1)$ adjusts the strength of habit formation in consumption, where C_{t-1} denotes aggregate (within household type) consumption in the previous period. The parameter β controls the rate at which the household discounts future utility, and ε_t^d represents a shock to this discount rate. As noted previously, the expectations operator denotes beliefs formed under bounded rationality such that agents think the economy will return to steady state more rapidly than it actually does in equilibrium.

In maximising the above expression, household expenditures in each period must not exceed household income. Income consists of wages (taxed at a rate $\tau_{n,t}$), profits from the ownership of firms, interest received for holdings of long-term bonds (foreign and domestic), and lump sum rebate of transaction costs for long-term bonds. If the household is of unrestricted type, then they also receive interest on holdings of domestic short-term bonds. Expenditures consist of consumption (subject to a tax at rate $\tau_{c,t}$), lump sum taxes, and purchases of new bond holdings. Purchases of long-term home and foreign bonds are subject to transaction costs at rates ξ_H and ξ_F respectively.

More formally, the budget constraint of restricted households, with expenditures on the left hand side and income on the right hand side, is

$$\begin{aligned} &P_t(1 + \tau_{c,t})c_t^r + P_{L,t}B_{H,L,t}^r + (1 + \zeta_{F,t})S_t P_{L,t}^* B_{F,L,t}^r + T_t^r \\ &\qquad = P_{L,t}R_{L,t}B_{H,L,t-1}^r + S_t P_{L,t}^* R_{L,t}^* B_{F,L,t-1}^r + W_t(1 - \tau_{n,t})n_t^r + D_t^r + \Xi_t^r, \end{aligned} \tag{2}$$

[18] The exact functional form is $u(c_t - \varkappa C_{t-1}, n_t) = \log(c_t - \varkappa C_{t-1}) - \frac{n_t^{1+\varphi}}{1+\varphi}$.

where c_t^r is consumption, $B_{H,L,t}^r$ and $B_{F,L,t}^u$ are holdings of long-term home and foreign bonds (respectively), T_t^r are lump sum taxes, n_t^r is hours worked, and D_t^r are nominal dividends from firm profits. Moreover, P_t is the consumer price level, $P_{L,t}$ and $P_{L,t}^*$ are domestic and foreign bond prices (respectively), $R_{L,t}$ and $R_{L,t}^*$ are domestic and foreign bond yields to maturity (respectively), and W_t is the nominal wage rate. Additionally, $\tau_{c,t}$ is the consumption tax rate, $\tau_{n,t}$ is the labour income tax rate, and S_t is the home nominal exchange rate. Finally, $\zeta_{F,t}$ are adjustment costs on foreign long-term bond holdings, which are rebated back lump sum through Ξ_t^r. Analogously, the constraint for unrestricted households is

$$\begin{aligned}P_t(1+\tau_{c,t})c_t^u + B_{H,t}^u + (1+\zeta_{H,t})P_{L,t}B_{H,L,t}^u + (1+\zeta_{F,t})S_tP_{L,t}^*B_{F,L,t}^u + T_t^u \\ = R_{t-1}B_{H,t-1}^u + P_{L,t}R_{L,t}B_{H,L,t-1}^u + S_tP_{L,t}^*R_{L,t}^*B_{F,L,t-1}^u + W_t(1-\tau_{n,t})n_t^u + D_t^u + \Xi_t^u, \quad (3)\end{aligned}$$

where $B_{H,t}$ denotes domestic short-term bond holdings.

Firms There exist three types of firms in the economy. In typical New Keynesian tradition, at the lowest level are monopolistic firms that produce differentiated goods to meet the demand of the firms one level above them in the production chain. They take this demand schedule as given, but use their market power to choose the price of their product to maximise their profits. These profits consist of proceeds from sales at the selected price, less wages paid to households, and are received by the firm owners as dividends. While these firms are able to adjust their prices in response to economic conditions, they can only do so with probability θ_H (or θ_F in the foreign economy), following Calvo (1983).

Middle layer firms combine low level goods using a bundling technology. Here, this technology[19] generates increasing price elasticity of demand for lowest-level inputs, so that relative price cuts do less at the margin to boost demand, the larger they get. Likewise, relative price increases cause demand to fall off more at the margin, the larger they are. Optimal firm behavior will tend to increase prices until (expected, future) marginal revenue offsets (expected, future) marginal costs (e.g. wages) in the event that the latter increase, such as in a sharp recovery. Since price increases make demand more elastic, they must rise more to align marginal revenue and marginal costs in this case. Likewise, declining demand elasticity means they have to adjust less in a sharp downturn.[20] These non-linear properties of firm demand, and the resultant Phillips curve, are important to capture inflation dynamics during large shocks such as those during COVID-19 and the subsequent recovery.

[19] Specifically, the technology is akin to that used in Dotsey and King (2005) and Levin, Lopez-Salido, and Yun (2007). Given demand Y for the final good, it combines intermediates y_i according to the condition $\int_0^1 G\left(\frac{y_i}{Y}\right)\ di = 1$ where $G(x) = \frac{\phi}{1+\psi}[(1+\psi)x-\psi]^{\frac{1}{\phi}} - \frac{\phi}{1+\psi} + 1$. This class nests those of Dixit and Stiglitz (1977) for $\psi = 0$ and Smets and Wouters (2007) for $\psi < 0$.

[20] For the precise form of this technology, see Erceg et al. (2024). For a detailed explanation of the intuition behind how this choice affects firm decisions with flexible prices, see Harding, LindÃÂ© and Trabandt (2022, 2023).

The highest layer of production consists of perfectly competitive aggregator firms that combine domestic and imported goods to produce final goods that satiate private and public sector demand.

Government The fiscal authorities in each economy may issue short- and long-term bonds, collect lump sum taxes, and collect revenue from taxes on consumption and labour. They do so in order to pay interest on previously issued bonds, as well as to finance the governments' own expenditures. These expenditures are exogenous, following an AR(1) process. Additionally, the government receives any profits or losses from central bank asset purchases.

Long-term bonds are modeled as in Woodford (2001), and pay an exponentially decaying coupon. In particular, if the coupon rate is κ, then the bond holder receives the stream of payments $1, \kappa, \kappa^2, ...$, with one payment each period. The size of this coupon along with the price of a bond $P_{L,t}$ then determines the long-term yield, $R_{L,t}$.

We can define nominal consolidated government debt as current short-term bonds outstanding, plus the discounted sum of future coupons on long-term bonds. Note that this measure of consolidated debt is based on its face value, and does not include the mark-to-market price of the bonds. Formally, the government's budget constraint in the small economy is given by

$$B_{H,t} + P_{L,t}B_{H,L,t} + T_t + \Phi_t^{CB} = R_{t-1}B_{H,t-1} + P_{L,t}R_{L,t}B_{H,L,t-1} + P_t g_t, \tag{4}$$

where $B_{H,t}$ and $B_{H,L,t}$ are respectively short- and long-term bonds issued by the government, $T_t$is a lump sum transfer, $\Phi_t^{CB}$are profits or losses made on the central bank balance sheet and transferred back to the government, and $g_t$is the government's own operating expenses, exogenously given.

Central bank The central bank adjusts the policy rate according to a monetary policy rule,reacting to deviations of inflation from target with a response coefficient γ_π, responds to deviations of output growth with weight γ_y, and smooths interest rates with weight γ_r. The prevailing nominal rate R_t is constrained by an ELB $\underline{R}$, so that

$$R_t = \max\left(\widetilde{R}_t, \underline{R}\right). \tag{5}$$

Here, the shadow rate $\widetilde{R}_t$ is given by the central bank's Taylor rule

$$\frac{\widetilde{R}_t}{\overline{R}}\varepsilon_t^d = \left(\frac{\widetilde{R}_{t-1}}{\overline{R}}\varepsilon_{t-1}^d\right)^{\gamma_r}\left[\left(\frac{\pi_t}{\pi_{t-1}}\right)^{\gamma_\pi}\left(\frac{y_t}{y_{t-1}}\right)^{\gamma_y}\right]^{1-\gamma_r}\varepsilon_t^r, \tag{6}$$

where π_t denotes the rate of consumer price inflation, y_t denotes output, $\overline{R}$ denotes the steady-state nominal rate, and ε_t^r is a monetary policy shock.

The central bank can also purchase long-term bonds on the secondary market via an exogenous shock ε_t^{CB}, financed by issuing short-term reserves to unrestricted domestic agents that pay the short-term rate. Defining the market value of central bank holdings of government bonds as $QE_t = P_{L,t}B_{L,t}^{CB}$, then we assume that this market value evolves according to the rule

$$QE_t = \left(1 + (1-\varrho)\left(\kappa \frac{P_{L,t}}{P_{L,t-1}} - 1\right)\right) QE_{t-1} + \varepsilon_t^{CB}, \tag{7}$$

where $0 < \varrho < 1$ is a parameter which reflects the central bank's reinvestment strategy.[21] In other words, absent bond price fluctuations or additional purchases by the central bank, the holdings mean revert to zero at a rate $1-(1-\varrho)(1-\kappa)$. This mean reversion happens more quickly if bond prices are rising, and more slowly if they are falling. Central bank profits on its asset portfolio are given by

$$P_{L,t}R_{L,t}B_{L,t-1}^{CB} - R_{t-1}B_{t-1}^{CB}, \tag{8}$$

where B_{t-1}^{CB} denotes the quantity of reserves issued to finance bond purchases.

Market clearing In equilibrium, the sum of consumption by restricted and unrestricted agents along with government expenditures must equal output produced by the final goods firm. The demand for labour from the intermediate goods firms must be matched by the supply of labour from the households.

Bond markets in the economy must also clear. This requires that short-term bonds issued by the domestic government and reserves issued by the domestic central bank must total those held by domestic unrestricted households. Meanwhile, long-term bonds issued by the domestic government must total those held by all households, foreign and domestic, in addition to those held by the domestic central bank.

This means that purchases of long-term bonds by the central bank will increase overall demand in the market for these assets. If supply does not adjust, this means that fewer such bonds are available to the private sector, and prices must rise in order to clear the market. Since the bond yield at any given time is the interest rate at which we discount all future coupon payments in order to arrive at the current price, a higher price implies weaker discounting, or in other words a lower yield.

[21] Absent any reinvestment strategy, the central bank's asset portfolio will adjust in value due to mechanical maturation (coupon payments) and fluctuations in bond prices. To maintain a constant portfolio value, the central bank would need to adopt a strategy which completely offsets these adjustments, e.g. $\varrho = 1$. More generally, the rule here assumes that the central bank offsets a fraction ϱ of these adjustments by purchasing current period bonds. See Appendix E in Erceg et al. (2024) for further details.

B Calibration strategy

We calibrate the model to achieve a number of objectives. Some parameters are set as in Erceg et al. (2024) or Kolasa, Laséen, and Lindé (2025) to represent general features of small and large open economies. Some are set to match certain features of the New Zealand economy in 2019, specifically. Others are calibrated based on estimates for New Zealand in the literature, namely calibrated and estimated values in Kamber et al. (2015). Finally, some parameters are chosen to match literature on the response of the economy to various policies. The resulting parameter values specific to New Zealand are shown in Table 1.

First, the size of the small economy ω in the model is set to 0.009 to approximately match the size of the New Zealand economy (StatsNZ, 2020 and Reserve Bank of New Zealand, 2025) relative to that of the United States (U.S. Bureau of Economic Analysis, 2025) in 2019. The duration of the long-term bond in the model, ω_L, is set to 25.4 quarters, to approximately match that of outstanding New Zealand government bonds such as that reported in New Zealand Debt Management (2019). Likewise, the bond share bg_{ss} held by domestic agents in the steady state is set to 0.528, the value reported in New Zealand Debt Management (2019). The steady-state debt to quarterly GDP ratio $\overline{B}_g$ is set to 1.088, based on the 2019 gross debt level reported in The Treasury (2024). Steady-state government consumption as a percentage of GDP $\overline{G}$ is set to be 0.1887, as reported by World Bank Group (2025) for New Zealand in 2019, and the steady-state labour income tax rate $\overline{\tau}_n$ is set to 0.184, the 2019 average for New Zealand reported in OECD (2020).

Turning to parameters which are selected to match estimates in Kamber et al. (2015), the reciprocal φ of the household's Frisch elasticity of labour supply is set to 1.16. Likewise, the central bank's Taylor coefficient γ_π and weight on the output gap γ_y are set to 1.97 and 0.2 respectively.

Additionally, several parameters are set close to those estimated in Kamber et al. (2015), but modified to better match impulse responses to policy shocks. For example, the home bias for private consumption goods θ_c is set to 0.7, a value which is not too dissimilar from the value of 0.56 implied by Kamber et al. (2015)[22] but which also allows us to more closely match the response of output to a monetary policy shock in that paper. Likewise, the parameter governing habit formation $\varkappa$ is set to 0.6, once again close to the value of 0.5 in Kamber et al. (2015) obtained by Bayesian estimation, but adjusted to match the response of consumption to a

[22] Specifically, Kamber et al. (2015) chooses the share of tradable goods in the consumption basket to match the share of tradable goods in the CPI, which was 0.44.

Parameter	Interpretation	Value	Target
ω	Size of small economy	0.009	NZ GDP/US GDP
η_c	Home bias in private consumption	0.7	Trad. share in GDP 0.4, GDP response
η_g	Home bias in public consumption	0.75	Lower fiscal multiplier
θ_H	Calvo probabilityof price change	0.6	Match CPI inflation response
φ	Inverse of labour supply elasticity	1.16	Kamber et al. (2015)
$\varkappa$	Strength of habit-formation	0.6	Kamber et al. (2015) value 0.5, Match consumption response
$\overline{\text{Dur}}$	Duration	25.4	New Zealand Debt Management (2019)
ω_L	Share of long-term bonds	0.9751	Nominal value ($\geq$1 year)
$\overline{B}_H/\overline{B}_H^*$	Bond share held by home	0.528	New Zealand Debt Management (2019)
γ_r	OCR inertia	0.9	0.84 in Kamber et al. (2015), Match several responses
γ_π	OCR response to inflation	1.97	Kamber et al. (2015)
γ_y	OCR response to output growth	0.2	Kamber et al. (2015)
$\overline{B}_g$	Debt/QGDP	1.088	The Treasury (2024)
$\overline{G}$	Per capita govt. exp.	0.1887	World Bank Group (2025)
$\overline{\tau}_c$	Steady-state consumption tax	0.15	GST rate
$\overline{\tau}_n$	Steady-state labour income tax	0.184	OECD (2020)
ρ_g	Persistence of govt spending process	0.88	Kamber et al. (2015)
ξ_H	Long-term bond adj. cost	0.025	LSAPs IRF
μ^*	Price elasticity of export demand	-5	Exports IRF

Table 1: Calibration.

monetary shock. Lastly, the interest rate smoothing parameter γ_r is set to 0.9, slightly higher that the estimated value of 0.84 in Kamber et al. (2015).[23]

Parameters chosen solely to better match the responses to policy shocks include the Calvo probability θ_H of a monopolistic firm in the small country being able to adjust its price in a given period. This is set to 0.6 to better match the inflation response. Similarly, the home bias for government consumption η_g is set to 0.75 to limit the size of the output response to a government expenditures shock in line with the literature on fiscal multipliers in New Zealand, described in detail below. Finally, the cost of adjusting one's long-term bond portfolio in each economy ξ_i, $i = H, F$ is set to 0.025 in order to limit the output response to exogenous asset purchase shocks by the central bank, following the approach of Kolasa, Laséen, and Lindé (2025).

C Dynamics triggered by policy shocks to the OCR and government consumption

Our calibration of the model partially depends on how well the parameterisation can help the model match prior econometric evidence for New Zealand. In particular, we examine how well the model dynamics triggered by conventional monetary policy shocks and government consumption expenditure shocks. For this reason, it is useful to examine the impulse response functions associated with these policy shocks.

In Figure 13, we first consider the response of the domestic economy to a monetary policy shock (in Equation 6) which reduces the OCR by 1 percentage point. The shock impacts the economy through its effects on private sector savings, the exchange rate, and household expectations. In particular, the lower policy rate motivates unrestricted households to save less and consume more in the near term, increasing demand for output and putting upward pressure on prices. The decline in short-term rates transmits to the long-term rate, reinforcing this mechanism for unrestricted households as well as transmitting through to restricted households. Moreover, to prevent the potential for arbitrage between higher interest yielding foreign bonds and domestic assets the exchange rate must depreciate, increasing foreign demand for domestic goods. Finally, households expect these conditions to persist for some time after the initial shock, so that it takes some time for the economy to return to its long run equilibrium.

[23] For a detailed comparison of the response of the model to the RBNZ's central forecasting model, see Appendix B.

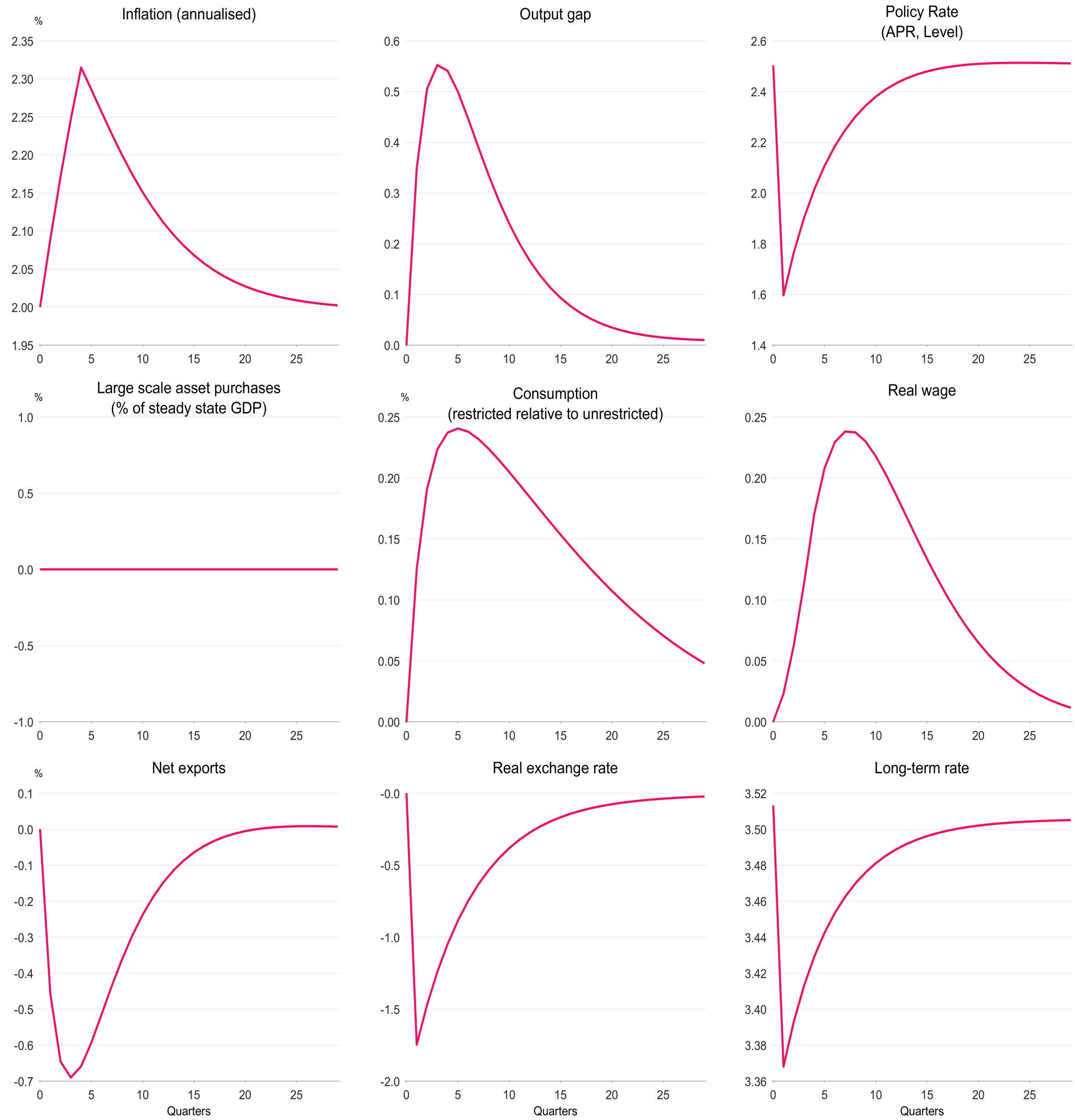

Figure 13: Impulse responses to a monetary policy shock.

Parameter	NZSIM	This Model
Inflation	0.3	0.31
Output	0.75	0.55
Consumption	1.0	0.85 (unrestr.), 1.1 (restr.)
Exports	0.15	0.12
Imports	0.8	0.68
Wages	0.25	0.24
Real Exchange Rate	-1.25	-1.75

Table 2: Peak responses to a monetary policy shock.

Table 2 compares the peak of the responses of our model to a monetary policy shock to that of the Reserve Bank's central forecasting model, NZSIM, as reported in Kamber et al. (2015). We find that several of the responses match quite closely. In particular, the responses of inflation, wages, and exports are nearly identical between the two models. While the response of output and imports are larger in NZSIM, they are nonetheless of comparable magnitude, in particular relative to the other responses reported in the table. The consumption response of unrestricted agents in the present model is slightly smaller than the aggregate response in NZSIM, while that of restricted agents is larger by about the same amount. The main deviation between the two models shows up in the response of the real exchange rate, which is smaller in NZSIM than in the current model. This is likely the result of a risk premium which is applied to foreign bond holdings in NZSIM in order to capture deviations from uncovered interest rate parity and dampen the exchange rate response to shocks.

Figure 14 shows the response of the economy to a fiscal policy shock which increases government consumption (in Equation 4). In particular, this shock increases the fiscal authority's demand for goods in manner which does not increase household welfare or production in the economy and enters as increased expenditure for the government. This significantly increases demand for domestic and imported goods, while the central bank policy rate reacts endogenously to this impulse by increasing the policy rate, limiting the impact on inflation. Meanwhile the exchange rate appreciates to offset the interest rate differential due to higher policy and long-term rates in the domestic economy. The increase in domestic demand and higher exchange rate results in fewer domestic goods being exported to the foreign economy. Moreover, government expenditures somewhat crowd out the consumption of restricted households in the domestic economy while having a minimal impact on that of unrestricted households.

Recall that the home bias for public consumption in the model was chosen to match the fiscal multiplier for government expenditures. This multiplier can be roughly computed by dividing the peak impact of the expenditures shock on output by the size of the shock itself, which in

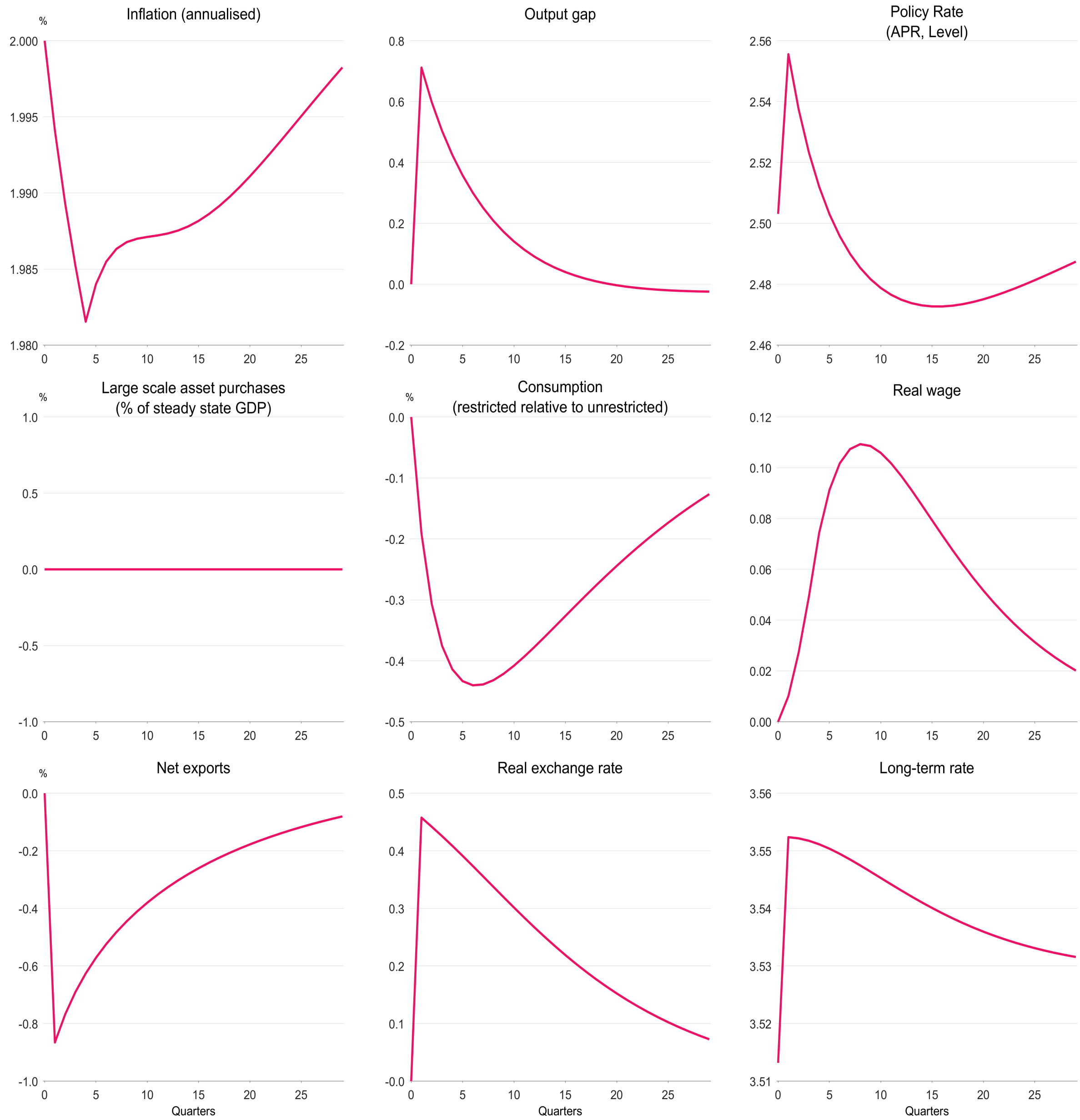

Figure 14: Impulse responses to a government expenditure shock.

Figure 14 is about 0.25 percent of annual steady-state GDP. The output response shown in Figure 14 is stated as a percentage of quarterly steady-state output, so that the fiscal multiplier is approximately $0.7/4 \times 0.25$ or 0.7. Comparing this to the literature for New Zealand as surveyed in Hamer-Adams and Wong (2018), we see that the multiplier in the model is at the upper end of the range of 0.3-0.8 of the estimates for government consumption.

D COVID-19 shock calibration

Recall that we denote the shock to the household discount factor by $\varepsilon_{d,t}$ in Equation 1. Additionally, let $i_{t,s}$ denote the RBNZ forecast of the policy rate s periods ahead, in the quarter corresponding to period t, so that $0 \leq s \leq S$ where S is the forecast horizon. Moreover, let $\epsilon_{C,t,s}$ denote LSAP shocks calibrated to what was announced for s periods ahead, $0 \leq s \leq S$, at or before time t. Finally, let $I_{t,s}$ denote a model implied policy rate track given shocks up to time t. In detail, the shock selection procedure is as follows:

1. Begin with the economy in the steady state at $t = -2$.
2. Find a value of $\varepsilon_{d,-2}$ which puts the policy rate at 1 percent at $t = -1$, the level of the New Zealand official cash rate in 2019Q4.[24]
3. Find a value of $\varepsilon_{d,-1}$ which puts the OCR at the ELB for one year (beginning the following period).
4. For $t = 0, ..., 7$, starting at the state of the economy following previous shocks, and given the shocks $\epsilon_{C,t,s}$, $0 \leq s \leq S$, find a value of $\varepsilon_{d,t}$ such that the duration of the ELB in the model matches that in the RBNZ's forecast policy rate for the corresponding quarter.
5. For $t = 8, ..., 12$, starting at the state of the economy following previous shocks, find a value of $\varepsilon_{d,t}$ that minimises

$$\sum_{s>t:i_{t,s+1}>i_{t,s}} (I_{s,t} - i_{s,t})^2 \tag{9}$$

6. For $t = 13, ..., 20$, starting at the state of the economy following previous shocks, find a value of $\varepsilon_{d,t}$ that minimises

$$\sum_{s\geq t} (I_{s,t} - i_{s,t})^2 \tag{10}$$

[24] The model economy's response to a shock does not happen until the period following the shock itself.

At the conclusion of this procedure, we are left with values for $\varepsilon_{d,t}$ for $t = -2, ..., 20$, which we will use in the counterfactual experiments described in the next section.

E Scenario data

Variable	Data	Units
Policy Rate	Official Cash Rate (OCR)	Percent
Large Scale Asset Purchases	Securities - LSAP Programme	Percent of GDP
CPI Inflation	Consumer Price Inflation	Percent
Output	Output Gap	Percent
Long-term Rate	5 Year New Zealand Government Bond Rate	Percent
Real Exchange Rate	New Zealand Dollar Trade Weighted Index	$100 \times \log$
Tax Revenue	Sum of indirect taxation, corporate tax, and household tax	Percent of GDP
Government Debt	Gross sovereign issued debt (ex RB settlement cash and RB bank bills)	Percent of GDP

Table 3: Data used in scenarios.