# The Liquidity Premium under a Floor System of Monetary Policy

Cristián Cuevas *

This version: May 12, 2023

**Abstract**

Can a government exhaust the convenience yield on its debt by borrowing too much? Although it is usually assumed the answer is yes, available empirical results fail to find a significant negative effect of debt supply when monetary policy is taken into account: the liquidity premium is determined by the monetary policy rate set by the central bank, regardless of how much the government borrows. I show that one issue with these results is that, under a scarce-reserve system, the causal impact of government debt is confounded by the endogenous positive co-movement of the supply of reserves (set by the central bank), which is a close substitute. I use data from New Zealand to analyze the liquidity premium under a floor system, where the interest on reserves and their supply are disentangled. I find a negative causal impact of government debt and of the interest rate on reserves. A model explains the results, characterizes how fiscal and monetary policy interact to determine the convenience yield of government debt, and highlights two policy implications. First, under a floor system a monetary policy tightening can have a distinct negative impact on the fiscal capacity of the government through a reduction on the liquidity premium. Second, under a floor system the dynamics of the liquidity premium dampen monetary policy transmission to illiquid rates.

**Key words**: liquidity premium, monetary policy, fiscal policy.

**JEL codes**: E43, E52, G12.

*Georgetown University, 37th & O St NW, Washington, DC, USA. E-mail: cc1951@georgetown.edu. I am grateful for helpful comments from Dan Cao, Behzad Diba, and the participants at the 2022 Annual Meeting of the Midwest Economic Association. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

# 1 Introduction

Investors pay a premium for the liquidity service flows provided by government debt (beyond what standard asset pricing would predict for an asset with low liquidity risk) and this makes public debt a near-money asset that carries a convenience yield. Do liquidity premiums on government bonds depend on the supply of debt? Can a government exhaust the convenience yield by borrowing too much? The recent buildup of public debt in advanced economies to fight the Covid pandemic poses these new questions for the convenience yield literature. Although recent analyses of fiscal capacity assume the answer is yes (Mian et al., 2021; Jiang et al. 2022a), available empirical results fail to find a negative effect of debt supply: they show that the liquidity premium is determined by the monetary policy rate set by the central bank, regardless of how much the government borrows (Nagel, 2016). However, I show that isolating the role of the debt supply is challenging because it positively co-moves with the supply of reserves (endogenously set by the central bank) and of deposits, which are a close substitute in the provision of liquidity services and act as a confounding factor.

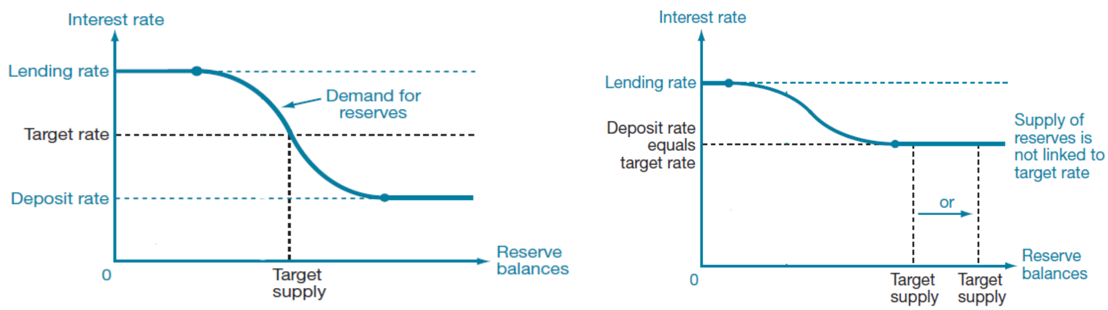
This paper argues that the way New Zealand conducted monetary policy allows one to circumvent the collinearity between reserves and government debt present in other data sets (including U.S. data), and in addition helps to isolate the role of the monetary policy rate set by the central bank. In particular, in July 2006, the Reserve Bank of New Zealand (RBNZ) transitioned to a floor system, where the central bank does not need to adjust the quantity of reserves to hit its monetary policy rate target. My results show that debt supply has a negative causal impact on the liquidity premium and that the interest on reserves, stripped of its linkage to reserves supply, also reduces the liquidity premium.

The potential exhaustion of convenience yields has significant fiscal and monetary policy implications. Convenience yields are at the center of current fiscal capacity analysis. When debt provides non-pecuniary services to investors, it allows the government to collect "debt revenue" or a form of debt seignorage, allowing the debt-to-GDP ratio to be above the discounted present value of primary surpluses (Reis, 2021; Jiang et al., 2022b). Moreover, liquidity premia lower short-term equilibrium interest rates (Lenel et al., 2019) and are at the center of unconventional monetary policy transmission in Krishnamurthy and Vissing-Jorgensen (2011) and Del Negro et al. (2017).

In the first part of the paper, I show that central bank reserves and the supply of T-bills have a strong positive correlation (crowding-in) when central banks conduct monetary policy under a corridor system (or scarce-reserve system). The United States and other advanced economies implemented such a system until 2008. The central bank targets an interbank rate and supplies the amount of reserves that achieve that target through open market operations (see Figure 1a). If there is an increase in demand for liquidity by banks, the central bank prevents the interbank rate from increasing by supplying extra reserves. The same would happen if the government issued

Figure 1: Two Systems of Monetary Policy Implementation

(a) Corridor System (b) Floor System




more T-bills (which also provide liquidity to banks). If reserves and T-bills are close substitutes and move together along the cycle, then regressions of the liquidity premium on both the interbank rate and the supply of T-bills suffer from multicollinearity, and the supply of reserves is a confounding factor for identifying the causal impact of Treasury supply.

To isolate the causal impact of the supply of government debt on the liquidity premium, one needs to look at instances where the central bank hits its monetary policy rate target without altering the supply of reserves. Monetary policy implemented through a floor system offers such an opportunity. The central bank supplies abundant reserves to the point where the demand for liquidity by banks no longer responds to the quantity of reserves (see Figure 1b; banks' demand for reserves becomes flat as in Poole's (1968) model). In this scenario, the monetary policy rate used by the central bank to hit its target is the interest it pays on these reserves (the IOR). The supply of reserves ceases to be endogenous to the stance of monetary policy and along with the IOR they are now two independent tools. Therefore, a regression analysis of the liquidity premium on the supply of T-bills uncovers the causal impact of the debt supply. Including the IOR in the regression uncovers the effect of the monetary policy rate that works not through the quantity of reserves.

I implement this exercise empirically. Although the U.S. Federal Reserve has conducted something close to a floor system since late 2008 (when it increased the reserve supply and started paying interest on them), the U.S. data is unsuitable for this purpose. This is because the Quantitative Easing (QE) programs deployed in 2009-2014 endogenously altered the supply of reserves and the IOR remained unchanged until December 2015. For this reason, I use data for New Zealand, whose central bank transitioned to a floor system in 2006 but did not reach the zero lower bound nor deployed QE until March 2020. The regression analysis shows that the supply of T-bills is a significant determinant of the liquidity premium and that the effect of the IOR is negative.

I propose a monetary model that can explain these results. The model highlights two margins that respond to the supply of liquidity. The first one is at the household level: they derive utility from consumption and holding liquid assets (for transaction services). The *households' cost of liquidity* is given by the spread between the illiquid rate and the rate on deposits, and I assume that the demand for these services is never satiated. The second one is at the banks' level: liquid assets reduce the costs of operations (cost of issuing deposits). I refer to this as the *banks' cost of liquidity*, and I assume that above some level of reserves supply this cost is zero, and at this point banks do not respond to the supply of reserves (banks are in their flat portion of their reserves demand). A central bank implementing monetary policy through a floor system supplies enough reserves so as to operate on this flat demand portion. My model highlights a novel mechanism through which an increase of the interest on reserves reduces the liquidity premium on government debt even when banks' cost of liquidity is unresponsive: the rise in the interest on reserves reduces the cost of liquidity for households, as the higher rate passes onto the yield on deposits. This effect reduces their willingness to pay for the liquidity of T-bills, resulting in a drop in their liquidity premium. At the same time, the rise in the IOR lowers the inflation rate, which increases the real value of existing liquid assets, and this increased real supply reduces the marginal benefit of liquidity.

Lastly, I use the model to show how monetary and fiscal policy interact in the determination of the liquidity premium of government debt. Unlike previous papers in the literature, I show that an increase in government debt issuance lowers the liquidity premium regardless of its degree of substitutability with deposits. Second, regarding monetary policy transmission, I show that, against the same shocks to the business cycle, a floor system requires responses of the monetary policy rate larger in magnitude than under a corridor system. Third, regarding fiscal sustainability, I show that monetary policy shocks have a negative impact on the fiscal capacity of the government, and this effect is proportional to the negative impact on the liquidity premium. The model is calibrated for New Zealand's data, but its implications are potentially important for the U.S. as well. The FOMC's January 2019 statement says that the Committee intends to keep an abundant reserves framework going forward, where the IOR is the primary tool for its monetary policy goals and "in which active management of the supply of reserves is not required".

**Literature review**. This paper contributes to the empirical literature on convenience yields by disentangling the role of the supply of government debt and monetary policy. While early papers found a negative impact of debt supply on convenience yields (Krishnamurthy and Vissing-Jorgensen, 2012; Greenwood et al., 2015), Nagel (2016) finds that the coefficient on the supply of debt loses all its significance once he adds the federal funds rate to the right-hand side of the regression. His interpretation relies heavily on the close substitutability of reserves and T-bills in the provision of liquidity services: the central bank can fully control the price of both assets by offsetting variations in debt issuance with the opposite variation of reserves. Building on this mechanism, Vandeweyer (2021) finds that T-bills supply becomes statistically significant in regressions using U.S. data after 2008. Based on this fact, he develops a model that explains why deposits and T-bills would no longer be perfect substitutes.

I show that the positive correlation between reserves and T-bills observed in the data does not support the crowding-out between reserves and T-bills at the center of these papers' mechanism. In addition, in New Zealand's data the interest on reserves shows more variation than in the U.S. after 2008, which is the data used in Vandeweyer (2021). On the theoretical side, my model contributes by explaining the effect of the interest on reserves on the liquidity premium under an abundant-reserves system. The model also complements Vandeweyer's (2021) by showing that under an abundant-reserve system, the supply of T-bills negatively affects the liquidity premium regardless of the degree of substitutability between debt and deposits.

More broadly, the idea that supply and demand effects can have important consequences in the Treasury market is central to a number of recent papers, including Greenwood and Vayanos (2010, 2014), Krishnamurthy and Vissing-Jorgensen (2011), Hanson and Stein (2015), and Vayanos and Vila (2021).

I also contribute to the recent literature that uses convenience yields to estimate the fiscal capacity of the government (Mian et al. 2021; Reis, 2021; Jiang et al. 2022a). The negative causal impact of government debt I estimate complements their models, which assume that larger outstanding debt reduces the "debt revenue" term. I also provide new insights on the role of monetary policy, which highlights the need for further research.

Finally, the model I propose contributes to the literature that explains the working of floor systems. I choose to rely on a monetary model as it better highlights the role of liquidity premia for both inside money (deposits) and government bonds. In this sense, my paper is closer to Cochrane (2014), Lenel et al. (2019), and Afonso et al., (2020). However, with the exception of Lenel et al. (2019), these models do not feature convenience yields. Floor systems have also been studied in New Keynesian models (see Curdia and Woodford, 2011; Canzoneri et al., 2017; Arce et al., 2020; Piazzesi et al., 2021; Benigno & Benigno, 2021), although their focus is rather on optimal policy and its impact on real activity. These models differ on how they account for the interbank reserves market, which allows for a role of the supply of reserves. Finally, in my model the supply of real debt will have an impact on equilibrium inflation, a feature shared by models of the fiscal theory of the price level (Cochrane, 2023). Unlike FTPL, however, my model ensures fiscal solvency and bonds provide transaction services.

The paper proceeds as follows. Section 2 explains the empirical strategy and its results, while Section 3 presents a model that can explain those results. Section 4 shows how monetary and fiscal policy interact in the determination of the liquidity premium of government debt. Section 5 concludes.

# 2 Empirical analysis

## 2.1 Empirical model

I begin by explaining my empirical strategy. A good starting point is to consider the following regression, which is widely used in the literature (Nagel, 2016; Vandeweyer, 2021):

$$LP_t = \beta_0 + \beta_1 FFR_t + \beta_2 (Tbills/GDP)_t + \epsilon_t \tag{1}$$

where $LP_t$ is the liquidity premium of T-bills, $FFR_t$ is the level of the monetary policy rate set by the central bank under a corridor system (the federal funds rate in the case of the United States) and $(Tbills/GDP)_t$ is the total supply of T-bills. Nagel (2016) estimates this regression for the United States with data from 1991 to 2011, when the U.S. Fed was mostly using a corridor system of monetary policy (until late 2008). His results show that $\hat{\beta}_1 > 0$ and $\hat{\beta}_2 = 0$. This leads Nagel (2016) to conclude that the supply of T-bills does not affect their liquidity premium, which would only depend on the level of monetary policy rate set by the central bank. The explanation would go as follows: under scarce reserves, the level of the federal funds rate is linked one-to-one with the supply of reserves, which in turn determines the cost of issuing deposits by banks. Deposits and T-bills must be very close substitutes in the provision of liquidity services and therefore the central bank, by elastically supplying new reserves, can fully control the price of both assets. For example, if the government were to suddenly supply less T-bills, the central bank can step-in by supplying more reserves, and private banks increase their supply of deposits. This implies a central bank that is continually offsetting new issuance of T-bills by an opposite change in the supply of deposits. At the end, the central bank defines the liquidity premium on all liquid assets (deposits and closer substitutes like T-bills), and the composition between the two is irrelevant.

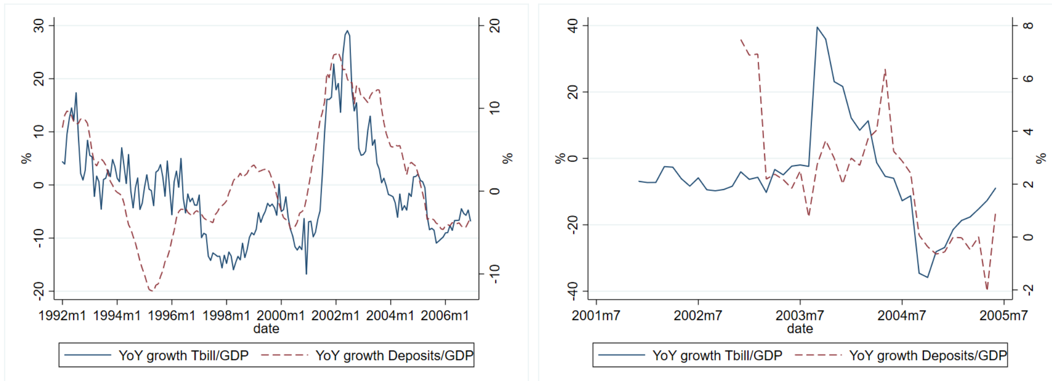
However, data for periods when central banks implemented a corridor system shows that T-bills and deposits do not crowd-out each other, but rather they are crowded-in. In Figure 2a I show the correlation between T-bills supply and deposits supply for the United States between 1992 and 2006. The correlation between the yearly growth rates of T-bills and Deposits is 0.62, significant at the 1% level. For New Zealand the sample is shorter, but a positive correlation still emerges (0.44, significant at the 1.4% level, for December 2001 to June 2005, before the floor system). This result is robust to using reserves-to-GDP instead of deposits [1].

Figure 2 suggests that both the supply of reserves and the supply of T-bills are endogenous and respond similarly to the business cycle. Since the federal funds rate is closely linked to the supply of reserves, the strong positive correlation between supply of reserves and T-bills implies that the

[1] The crowding-in is also consistent with the result in Krishnamurthy and Vissing-Jorgensen (2015), who estimate the extent to which Treasury debt crowds out short-term liabilities by the financial sector. They find an economically significant crowding out, but it works through Treasury supply crowding out non-checkable short-term debt (savings deposits) rather than liquid deposits like checking accounts.

Figure 2: Correlation between T-bills and deposits (scarce-reserve system)

(a) United States: Jan. 1992 - Dec. 2006 (b) New Zealand: Dec. 2001 - Jun. 2005




regression in (1) suffers from multicollinearity. Therefore, to isolate the causal impact of T-bills on their liquidity premium, one needs to look at instances where the central bank does not alter the supply of reserves to achieve its target.

In what follows, assume the following decomposition for the federal funds rate:

$$FFR_t = \gamma_1 i_t^m + \gamma_2 M_t^s + \gamma_3 (Tbill/GDP)_t \tag{2}$$

where $M_t^s$ is the supply of central bank reserves and $i_t^m$ is the interest paid on these reserves (IOR) by the central bank. The federal funds rate is the rate at which banks borrow reserves from other banks. Under a scarce-reserve system, banks are willing to pay a premium (above the interest on reserves) for the liquidity of reserves. As they operate in the downward-sloping portion of their demand for liquidity, a larger supply of reserves lowers the willingness to pay for them, and so $\gamma_2 < 0$. T-bills also work as liquid assets. If the government increases the supply of T-bills, this will increase their yield and will be a more attractive source of liquidity to banks. This will increase the equilibrium rate in the money market in genral and in the interbank market in particular, forcing the central bank to issue more reserves to prevent money market rates from going over the target. As a result, the expected sign of $\gamma_3$ will also be negative.

The true model for the liquidity premium would then be:

$$LP_t = \beta_0 + \beta_1\gamma_1 i_t^m + \beta_1\gamma_2 M_t^s + (\beta_1\gamma_3 + \beta_2)(Tbill/GDP)_t + \epsilon_t \tag{3}$$

Equation (3) shows that the effect of the supply of debt on the liquidity premium can be decomposed into a direct effect (for which Nagel (2016) estimates $\hat{\beta}_2 = 0$), and an effect working through their substitutability with reserves ($\beta_1\gamma_3$, and we know $\hat{\beta}_1 > 0$).

I claim that a floor system offers the opportunity to analyze the liquidity premium at instances where the central bank does not need to alter the supply of reserves to achieve its target. Under a floor system, the central bank issues abundant reserves, beyond the point where reserve demand by banks becomes flat (and does not respond to supply). This can be understood through the model of banks' reserve demand in Poole (1968) or Afonso et al. (2020). In these models, banks demand reserves only to meet reserve requirements, and there are no frictions in the interbank market. At high levels of aggregate reserves, demand is flat, with banks indifferent among a wide range of reserve holdings as long as market rates (including the interbank rate) equal the interest rate paid on reserves. Since in this case central banks operate on the flat part of the banks' demand for reserves, they in practice have two independent instruments: the policy rate (the interest on reserves) and the supply of reserves. The former is used to meet its mandate on inflation, and the latter can be used for some other goal. Importantly, the supply of reserves is no longer endogenous to the conduct of monetary policy and clears up this confounding factor of the impact of debt supply.

As monetary policy implemented through a floor system does not work through the supply of reserves, I assume that $\gamma_2 = 0$ in (3). Therefore, I estimate the following regression:

$$LP_t = \alpha_0 + \alpha_1 i_t^m + \alpha_2 (Tbill/GDP)_t + \epsilon_t \tag{4}$$

In this equation, coefficients will have a different interpretation as in (1). $\alpha_1$ captures the effect of the level of interest rates stripped from its effect through the supply of reserves. A monetary policy tightening (an increase in the IOR) no longer involves a decrease in the supply of reserves. What is the the expected sign of $\widehat{\alpha}_1$? If the central bank pays a higher yield on its reserves, banks will ask for a higher yield on T-bills in order to be willing to hold them. A higher yield on T-bills is achieved by a lower liquidity premium. Therefore, we should expect $\widehat{\alpha}_1 < 0$. The coefficient $\widehat{\alpha}_2$ will capture the causal effect of the supply of T-bills, no longer confounded by the collinearity with the supply of reserves.

The U.S. Federal Reserve has managed something very close to a floor system since October 2008 when it expanded the supply of reserves and started paying interest on them. However, for most of the time since then, this policy has coincided with the conduct of QE (where reserve supply becomes endogenous) and didn't alter the IOR for seven years. For that reason, I study the liquidity premium under a floor system with data from New Zealand. In July 2006, the Reserve Bank of New Zealand (RBNZ) began the transition from a symmetric channel system to a floor system (see the Appendix for a detailed description of this transition and its main elements). The level of reserves went from NZ$20 million approx. to around NZ$8 billion in a few months. This level was kept steady until March 2020. At the same time, the interest on reserves (called Official Cash Rate) was set equal to the interbank rate. Importantly, New Zealand did not reach the zero lower bound nor conducted QE until the Covid crisis in March 2020 (where reserves supply was raised to almost NZ$30 billion), and so it is an ideal scenario to study a floor system.

Data for New Zealand provides support to the assumption that reserves supply is no longer endogenous to monetary policy under a floor system. The correlation between the interest on reserves and the supply of reserves is not significantly different from zero (for comparison, under a scarce-reserve system, the correlation between the federal funds rate and the supply of reserves is significantly negative). At the same time, in New Zealand the correlation between T-bills and reserves is also not significantly different from zero, showing the disconnection between the two under a floor system. The Appendix shows these correlations graphically. It also addresses two specific episodes in which the RBNZ injected liquidity into the banking system, which were most likely driven by liquidity concerns and therefore endogenous.

## 2.2 Data

I follow the literature's convention and measure the liquidity premium of T-bills by taking their spread against other assets of similar maturity and credit risk. The intuition is that, since the maturity and credit risk are the same, the remaining spread must be due only to their liquidity services. The spread, then, is a measure of the extra price investors are willing to pay for the liquidity of the T-bills. For New Zealand data, I use two assets that are comparable to T-bills: 3-month bank bills and 6-month term deposits.

Bank bills are a common investment in Australia and New Zealand: it is a promise by the borrower to pay the face value at maturity. It is considered a safe investment because they are "accepted" (guaranteed) by a bank. In accepting the bank bill, the bank makes the payment at maturity, regardless of the repayment ability of the borrower. Investors can buy bank bills from a bank, for an agreed face value, an agreed term, and a quoted rate of interest. The bank bills are then endorsed by the bank to acknowledge the change in ownership. Upon maturity, the bank will pay the full face value, which includes the initial purchase price and the interest receivable. An additional feature of investing in bank bills is that should you require funds before the due date, the bank will purchase the bank bill at the prevailing interest rate. Although this last feature might make them as liquid as a T-bill, they have consistently traded at yields above T-bills, with the spread spiking during the turmoil of 2008.

On the other hand, the spread between term deposits rates and T-bill rates are one of the measures used in Krishnamurthy and Vissing-Jorgensen (2012) for U.S. data. Term deposits in New Zealand, similar to the U.S., are a safe investment where investor lock-in a competitive interest rate for a fixed term. Investors are usually not allowed to redeem their money before the term's expiration. Some banks allow it in specific circumstances and require early notifications to do so. Therefore, the spread should account for the liquidity provided by the T-bill.

The liquidity premium measured with these two assets is sizable. The bank bill has a yield 28 basis points above T-bills on average for January 1996-July 2021. The term deposit has a larger spread, of 63 basis points on average. The larger spread for the term deposit might come from two sources. First, its maturity is six months rather than three. Second, this might be due to the higher liquidity of the bank bill, which makes it more similar to the T-bill. Recall that the bank bill can be sold at any time during the term of the instrument, while the investment in the term deposit is locked in for the whole term. Standard deviations are high for both measures: 24 and 80 basis points, respectively.

### 2.3 Results

I estimate Equation (4) via instrumental variables. The dependent variable is the spread between the 6-month term deposit and the 6-month T-bill. Data starts in March 2009 (the month the New Zealand Treasury started auctioning 6-months instruments). The independent variables are the interest on reserves, the VIX index -to account for demand shifts due to uncertainty-, the supply of government debt (which I proxy by using the supply of T-bills or the supply of debt of all maturities), and the supply of deposits or reserves. The latter accounts for the few instances where the RBNZ injected reserves for endogenous reasons. I use two measures of the supply of deposits: total amount taken from the banking system's balance sheet, and total amount taken from the households' balance sheets. Newey-West standard errors correct for autocorrelation.

For robustness, in the Appendix I run the regressions using the spread between the 90-day Bank Bill and the 3-month T-bill as a measure of the liquidity premium. It also shows robustness to estimating the regression in first-differences and to dropping the Covid pandemic months.

Instrumental variables are important since an unobserved liquidity demand shock (correlated with interest rates or the supply variables) may induce the central bank to lower interest rates in the same month, leading to reverse causality. This would result in a downwardly biased estimate of the interest rate coefficient.

To instrument the interest on reserves I use futures prices, in the same way as Piazzesi and Swanson (2008). In particular, I use the generic future contract for the 3-month bank bill, available in Bloomberg. These are futures contracts that settle at the end of each month based on the average rate that prevails during that month. The futures price before expiration is a risk-adjusted forecast of the average rate that prevails during the expiration month. Used as an instrument, the futures price in months prior to the expiration month should therefore be highly correlated with the average policy rate during the expiration month.

To instrument the supply variable, I use nonlinear functions of the ratio of total debt to GDP. Greenwood et al. (2015) and Nagel (2016) use month dummies to exploit the strong seasonality in T-bill supply in U.S. data. This arises from seasonal fluctuations in tax receipts that are plausibly exogenous and immune to the reverse causality problem. This does not seem to work for New Zealand data. Nonlinear functions of total debt to GDP, instead, exploit the positive correlation

Table 1: New Zealand: Determinants of the liquidity premium - 2SLS

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| $ior_t$ | -0.323*** | -0.387*** | -0.214* | -0.217*** |
| | (0.1213) | (0.111) | (0.122) | (0.055) |
| $\log(\frac{Tbill}{GDP})_t$ | -0.446*** | -0.405*** | | |
| | (0.162) | (0.154) | | |
| $\log(\frac{Debt}{GDP})_t$ | | | -0.653* | -0.498* |
| | | | (0.340) | (0.276) |
| $\log(\frac{HHDeps}{GDP})_t$ | -4.628*** | | | |
| | (1.058) | | | |
| $\log(\frac{Deps}{GDP})_t$ | | -5.881*** | -1.386 | |
| | | (1.259) | (1.559) | |
| $\log(\frac{Reserves}{GDP})_t$ | | | | -0.953*** |
| | | | | (0.190) |
| $vix_t$ | -0.00106 | -0.00108 | -0.0098 | 0.0164 |
| | (0.0118) | (0.0128) | (0.0106) | (0.0117) |
| Constant | 4.348*** | 8.779*** | 3.7411 | -0.459 |
| | (0.996) | (1.741) | (2.377) | (0.525) |
| Instruments for: | | | | |
| IOR | Y | Y | Y | Y |
| Tbill/Debt supply | Y | Y | Y | Y |
| Deposits/Reserves | Y | Y | Y | Y |
| Weak instruments test | | | | |
| CD stat | 22.1 | 26 | 22.88 | 40.35 |
| SY critical value | 8.5 | 8.5 | 8.5 | 8.5 |
| Observations | 149 | 149 | 149 | 149 |
| R-squared | 0.254 | 0.287 | 0.2711 | 0.357 |

Notes: Data are at monthly frequency. Units are hundredth of basis points. Dependent variable is the 6-month Term deposit/Tbill spread. $\log(\frac{Debt}{GDP})_t$ includes outstanding government debt of all maturities. $\log(\frac{HHDeps}{GDP})_t$ are total deposits in households' balance sheet. $\log(\frac{HHDeps}{GDP})_t$ are deposits in the monetary base. Instruments for debt supply are nonlinear functions of the ratio of total debt to GDP. Instruments for the supply of deposits are nonlinear functions of the ratio of T-bills to GDP. A CD stat greater than the Stock and Yogo critical value rejects weak instruments (with bias greater than 10% of OLS bias). Newey-West standard errors in parenthesis (3 lags).

between total debt and its maturity structure. This instrument has been used, for example, in Krishnamurthy and Vissing-Jorgensen (2012).

Table 1 shows the results. Columns 1 and 2 use the supply of T-bills as a measure of the supply of government debt. The coefficient on T-bill supply is negative and significant. A one percent increase in the supply of T-bills reduces the liquidity premium by between 41 and 46 basis points. This result is robust to the measure of the supply of deposits used. The magnitude is lower than in Krishnamurthy and Vissing-Jorgensen (2012) but is much larger than the non-significant effect found by Nagel (2016) for the U.S. data.

Interestingly, the coefficient on the interest on reserves is significantly negative, which again is the opposite as in Nagel (2016). Table 1 shows the effect of the monetary policy rate stripped from its connection with the supply of central bank reserves and represents the effect of a monetary policy tightening under an ample-reserves system. This is a complete switch of the sign in the correlation between the monetary policy rate and the liquidity premium observed under a scarce-reserves system. The model in the next section will propose two channels to explain this negative effect and explore its implications. The Appendix shows that this negative coefficient also shows up for data in the U.S. after 2008, even though in that case the caveat of an endogenous supply of reserves still applies.

Columns 3 and 4 replicate the first two columns but including the supply of debt of all maturities as a proxy for the supply of government debt. Both the coefficient on the IOR and the negative effect of government debt are robust. A one percent increase in the supply of total debt reduces the liquidity premium by between 50 and 65 basis points.

Importantly, the instruments in Table 1 are strong as shown by the relatively high Cragg-Donald statistics. A statistic greater than the critical values from Stock and Yogo (2005) -also shown- rejects the hypothesis of weak instruments (with bias greater than 10% of the OLS bias) at a significance level of 5%.

# 3 Model

In this section, I set up a model that can explain the empirical results and that can characterize fiscal and monetary policy implications. In the model the liquidity premium arises at the household level, who derive convenience services from either deposits (issued by banks) or T-bills. This is slightly different from the discussion in Section 2.1, where the premium showed up at the banks' level, which derived liquidity from reserves or T-bills. I do this because it will allow me to compare the implications with those in Nagel (2016) and Vandeweyer (2021). In addition, reserves are one of the determinants for the supply of deposits, and it is reasonable to assume that ultimately banks are just intermediaries who want to serve households. Moreover, the households combine liquidity preferences with consumption-saving decisions, which are central to monetary policy.

This is an endowment economy-representative agent model comprised of households, who derive transaction services from liquid assets (deposits and T-bills); banks, who provide deposits by accumulating central bank reserves and other assets; a fiscal authority who sets the supply of T-bills; and a central bank that conducts monetary policy. I choose to rely on a monetary model with flexible prices as it better highlights the role of liquidity premia for both deposits and government debt.

### 3.1 Households

There is a single perishable consumption good with endowment stream $\{Y_t\}$. The endowment follows an exogenous process:

$$\text{log}Y_{t+1} = \rho_y \text{log}Y_t + \epsilon_{t+1} \quad , \epsilon_t \sim N(0, \sigma^2) \tag{5}$$

The representative household seeks to maximize the objective:

$$\mathbb{E}_0 \sum_{t=1}^{\infty} \beta^t [u(C_t) + \alpha \text{log}(Q_t)] \tag{6}$$

where $C_t$ is consumption and $Q_t$ is a real stock of liquid assets that the household draws service flows from. Liquidity services are supplied by money in the form of deposits and near-money in the form of T-bills issued by the government. Stock of liquidity is the CES aggregate:

$$Q_t = \left[ (1-\lambda) \left( \frac{D_t}{P_t} \right)^{\rho} + \lambda \left( \frac{B_t^h}{P_t} \right)^{\rho} \right]^{\frac{1}{\rho}} \tag{7}$$

where $\frac{D_t}{P_t}$ denotes real balances of deposits and $\frac{B_t^h}{P_t}$ denotes the real value of the household's T-bill holdings. $P_t$ is the nominal price of the consumption good. These liquidity benefits arise from some unmodeled use in intra-period transactions. A model period is one quarter, and T-bills have a one-period maturity.

The parameter $\rho$ controls the elasticity of substitution between T-bills and deposits. With $\rho = 1$, T-bills and deposits are perfect substitutes, and the composition of the aggregate liquidity supply is irrelevant. If they are imperfect substitutes, then $0 < \rho \leq 1$. The parameter $\lambda$ allows for differences in the relative contribution of T-bills and deposits to the stock of liquidity.

Households optimize subject to the flow budget constraint:

$$\begin{aligned} &D_t + B_t^h + k_t A_t - L_t + P_t C_t = D_{t-1}(1 + i_{t-1}^d) + B_{t-1}(1 + i_{t-1}^b) \\ &+ k_{t-1}(A_t + P_t Y_t) - T_t - L_{t-1}(1 + i_{t-1}) + \Omega_t \end{aligned} \tag{8}$$

where $B_t^h$ are the holdings of T-bills. $k_t$ denotes the share of total endowment stream that the household owns at the end of period $t$, $A_t$ is the price of the claim to the endowment stream, $T_t$

denotes transfers/taxes from the government, $i_t^b$ is the T-bill yield, $i_t^d$ is the interest rate on demand deposits, $L_t$ denotes loans, $\Omega_t$ is the flow of profits from banks to households, and $i_t$ is the nominal interest rate applicable to assets and transactions that do not produce a liquidity service flow.

The household first-order condition with respect to consumption yields the intertemporal Euler equation

$$1 = \beta \mathbb{E}_t \left[ \frac{u_c(C_{t+1})}{u_c(C_t)} \frac{1+i_t}{\Pi_{t+1}} \right] \tag{9}$$

where $u_c$ denotes the first derivative of $u(.)$ and $\Pi_{t+1} = P_{t+1}/P_t$. The illiquid rate $i_t$ in Equation (9) governs the household's intertemporal decisions, and thus this is the rate that the monetary authority is looking to affect. However, as explained below, the central bank's policy rate is the rate on deposits, $i_t^d$, which will carry a convenience yield and will trade below the $i_t$.

The first-order conditions with respect to real liquid asset balances are:

$$\frac{\alpha(1-\lambda_t)(\frac{D_t}{P_t})^{\rho-1}}{(1-\lambda_t)(\frac{D_t}{P_t})^{\rho} + \lambda_t(\frac{B_t^h}{P_t})^{\rho}} = u_c(C_t)\frac{i_t - i_t^d}{1+i_t} \tag{10}$$

$$\frac{\alpha\lambda_t(\frac{B_t^h}{P_t})^{\rho-1}}{(1-\lambda_t)(\frac{D_t}{P_t})^{\rho} + \lambda_t(\frac{B_t^h}{P_t})^{\rho}} = u_c(C_t)\frac{i_t - i_t^b}{1+i_t} \tag{11}$$

Equation (10) reflects the valuation of inside money, or deposits, by households. Since households derive transaction services from deposits they are willing to accept an interest rate on deposits $i_t^d$ that is below the intertemporal rate. The *households' cost of liquidity* $i_t - i_t^d$ reflects the value of money for making payments. It is declining in real balances: the marginal benefit of payment instruments is declining in the overall quantity held. Equation (11) has an analogous interpretation for T-bills and their yield, $i_t^b$. In this equation, $i_t - i_t^b$ corresponds to the *liquidity premium* of T-bills.

### 3.2 Banks

A model characterizing a corridor and/or a floor system needs to include an interbank market where the supply of reserves play a role (or not) in determining equilibrium interest rates. The literature has attempted this through different modelling choices: from a representative bank facing real intermediation and liquidity costs (Lenel et al., 2019; Curdia and Woodford, 2011) to a mass of banks facing idiosyncratic liquidity needs (Arce et al. 2020, Piazzesi et al. 2021). In this section I build on the framework of Curdia and Woodford (2011) because it nests a corridor and a floor system in the simplest way. However, implications are similar if I use, for example, the framework in Piazzesi et al. (2021).

The representative bank in this economy exists because households cannot access central bank's reserves directly. The bank therefore originates liquid deposits by either holding reserves at the central bank or holding other assets such as loans, $L_t^s$. Specifically, I assume banks take deposits, on which they promise to pay a riskless nominal return $i_t^d$ one period later and hold other assets (such as loans) on which they earn a nominal interest rate of $i_t$. They also choose a quantity of reserves $M_t^d$ to hold at the central bank on which they will receive a nominal yield of $i_t^m$. The bank takes all these interest rates as given. In what follows, lower-case variables denote real variables.

The representative bank faces an intermediation cost when issuing loans. In particular, the origination of $l_t$ real loans requires costly information in the amount of $\chi_t(l_t)$, with $\chi_t', \chi_t'' \geq 0$. In addition, the bank consumes real resources in managing liquidity, $\theta(\frac{l_t}{m_t^d})$, $m_t^d \equiv M_t^d/P_t$, where the cost is a positive function of the scale of operations and a decreasing function of central bank reserves held, $\theta_{lt} > 0$, $\theta_{mt} < 0$. This cost can be thought of coming from the chance of some loans not being repaid, or facing unexpected deposit withdrawals from households. Importantly, $\theta_{mt} < 0$ means that reserves are more useful for handling liquidity costs than other assets: if they are sufficiently scarce, banks are willing to pay a higher price. This is the demand curve that many central banks exploited before 2008: they targeted a positive spread between the interbank rate and the reserve rate (which was zero in the case of the US), and elastically supplied reserves to achieve that spread.

I also assume that for any scale of operations $l_t$, there exists a finite level of reserves $\overline{m}(l_t)$ for which $\theta_{mt} = 0$ for all $m_t^d \geq \overline{m}(l_t)$. This assumption resembles the banks' demand for reserves in the model of Poole (1968) and Afonso et al. (2020). This tries to capture that liquidity costs are increasing in the scale of operations (for example, higher chance of unexpected withdrawals and greater precautionary liquidity demand), decreasing in reserves (for instance, as they meet regulatory requirements and facilitate intraday operations), and that with a sufficiently large amount of reserves, reserve demand by banks becomes flat once they are above their precautionary demand level, $\overline{m}(l_t)$.

Each period, the representative bank decides a scale of operation , $l_t$, and the level of reserves to hold at the central bank, $m_t^d$. It then issues real deposits to households in the maximum quantity that it can repay, taking all rates as given:

$$(1 + i_t^d)d_t^s = (1 + i_t^m)m_t^d + (1 + i_t)l_t \tag{12}$$

The bank maximizes each period the earnings to its shareholders (the household), which are equal to the deposits not used to pay for loans and reserves. Therefore, the bank maximizes:

$$\Omega_t = d_t^s - m_t^d - l_t - \chi_t(l_t) - \theta(\frac{l_t}{m_t^d}) \tag{13}$$

The first order conditions with respect to loans and reserves are, thus:

$$\frac{i_t - i_t^d}{1 + i_t^d} = \chi_t'(l_t) + \theta_{lt} \tag{14}$$

$$\frac{i_t^d - i_t^m}{1+i_t^d} = -\theta_{mt} \tag{15}$$

The left-hand side of Equation (14) is the marginal benefit of an extra loan. The right-hand side shows the marginal cost: a higher intermediation cost. Similarly, Equation (15) equates the marginal cost of an extra reserve with its marginal benefit: a lower liquidity cost (as $\theta_{mt} < 0$).

The rate $i_t^d$ resembles the interbank rate that central banks target when implementing a corridor system (more on this later). Equation (15) represents the *bank's cost of liquidity.* For $m_t^d < \overline{m}_t$, equation (15) delivers a one-to-one relationship between the supply of reserves and the interbank rate. For a given level of $i_t^m$, an increase in the supply of reserves reduces the liquidity cost of banks (right hand side of the equation) and thus reduces the premium on reserves, reducing $i_t^d$ (in the left hand-side). If $m_t^d \geq \overline{m}_t$, $\theta_m = 0$, banks face no liquidity cost, and the interbank rate equals the interest paid on reserves, independently of the supply of reserves. Intuitively, since reserves are abundant, banks no longer pay a premium on them.

Notice that the presence of liquidity costs by banks is not essential for the liquidity premium to obtain. It is useful, however, to contrast the scarcity of safe debt that gives rise to the liquidity premium on government debt to the scarcity of central bank reserves that ended when the RBNZ implemented the floor system (in the case of the U.S., it ended with quantitative easing programs).

### 3.3 Government and Central Bank

The government is comprised of a fiscal authority and a central bank. The fiscal authority's flow budget constraint is given by:

$$B_t^s = (1+i_{t-1}^b)B_{t-1}^s + G_t - T_t - T_t^{cb} \tag{16}$$

where $B_t^s$ is total debt issued, $G_t$ is fiscal spending, $T_t$ are tax/transfers to the household, and $T_t^{cb}$ are transfers from the central bank.

The central bank buys government bonds and pays with the issuance of new reserves to the banking system. Its budget constraint is:

$$M_t^s + (1+i_{t-1}^b)B_{t-1}^{cb} = B_t^{cb} + M_{t-1}^s(1+i_{t-1}^m) - T_t^{cb} \tag{17}$$

where $M_t^s$ is the supply of reserves and $B_t^{cb}$ are its holdings of government bonds. Notice that $B_t^s = B_t^h + B_t^{cb}$, and therefore the budget constraint for the consolidated public sector is:

$$B_t^h + M_t^s = (1+i_{t-1}^b)B_{t-1}^h + M_{t-1}^s(1+i_{t-1}^m) + G_t - T_t \tag{18}$$

Letting $U_t = B_t^h + M_t^s$, the consolidated budget constraint becomes $U_t = U_{t-1} + Z_t$, where $Z_t = i_{t-1}^b B_{t-1}^h + M_{t-1}^s i_{t-1}^m + G_t - T_t$ is the total deficit, inclusive of interest payments.

In real terms, the budget constraint becomes:

$$u_t = \frac{u_{t-1}}{\Pi_t} + z_t \tag{19}$$

where lower case letters denote real variables and $\Pi_t = P_t/P_{t-1}$. I assume that fiscal policy is governed by a rule for setting the real deficit:

$$z_t = \zeta_t - \rho_g u_{t-1} \tag{20}$$

where $\zeta_t$ will be assumed to follow an exogenous path. The parameter $\rho_g$ captures the response of the current deficit to outstanding debt. A positive value resembles a government that follows a sustainable path, as described in Bohn (1998). For simplicity, I assume $G_t = 0$. In this model, bonds' transaction services will affect equilibrium inflation and, therefore, the fiscal and monetary policy will interact in a way absent in standard models where bonds do not provide transaction services. Canzoneri and Diba (2005) show that, in this type of frameworks, the government needs to set fiscal policy in real terms to achieve local determinacy in the inflation rate.

## 3.4 Monetary policy implementation

The monetary authority conducts monetary policy to meet an interest rate operating target, $i_t^{d*}$, according to the policy rule

$$i_t^{d*} = \psi \Pi_t^{\psi_\pi} e^{\xi_t} \tag{21}$$

where $\xi_t$ is an exogenous shock to monetary policy. This policy rule does not consider the possibility of a zero lower bound, as the calibration for New Zealand in the period before 2020 will not involve such episodes.

The choice of $i_t^d$ as the central bank's policy rate can be justified as follows. In reality, the Fed sets the federal funds rate, which is the rate at which banks trade reserve balances intraday among themselves. The federal funds rate can, therefore, be seen as the rate at which banks can obtain liquid funding whenever needed. Although in the model there is no interbank market, the policy rate $i_t^d$ captures the same idea: it is the rate at which banks can obtain liquid funding, but in this case from households. There are alternative ways of modelling an interbank market that gives a role to the supply of reserves (see, for example, Arce et al. (2020)), but introducing a more formal interbank market would complicate the model without improving the exposition of the underlying mechanisms.

The central bank can implement monetary policy along two dimensions. First, for a given $i_t^m$, it can influence the policy rate $i_t^d$ by altering the supply of reserves, $m_t^s$. This resembles a corridor system. By Equation (15), it is easy to see that in this case the supply of reserves is not an independent policy tool, as there is a one-to-one relationship between the supply of reserves and $i_t^d$.

Second, for a given level of supply of reserves, it can influence $i_t^d$ by altering $i_t^m$. I model the implementation of the floor system as the central bank setting $m_t^s > \overline{m}_t$ at all times. Therefore, by equation (15), $i_t^d = i_t^m$ and every period the central bank sets the interest on reserves, $i_t^m$. The supply of reserves becomes an independent tool as long as $m_t^s > \overline{m}_t$. To keep things simple, I assume the supply of reserves $m_t^s$ follows an exogenous random path that never falls below $\overline{m}_t$. This exogenous shock tries to represent random demand by households due to unexpected liquidity needs (change in precautionary demand or unexpected liquidity withdrawals by households). Besides this shock, the central bank does not endogenously set $m_t^s$.

This is a simple representation of how the Fed has conducted monetary policy since 2008. The interest rate on reserves and the federal funds rate are the tools used to reach its goals of inflation and unemployment, and the supply of reserves is not followed closely. Indeed, the Fed's January 2019 statement reads: "*The Committee intends to* ***continue*** *to implement monetary policy* ***in a regime in which an abundant supply of reserves*** *ensures that control over the level of the federal funds rate and other short-term interest rates is exercised primarily through the setting of the Federal Reserve's administered rates, and in which* ***active management of the supply of reserves is not required***" (emphasis is mine).

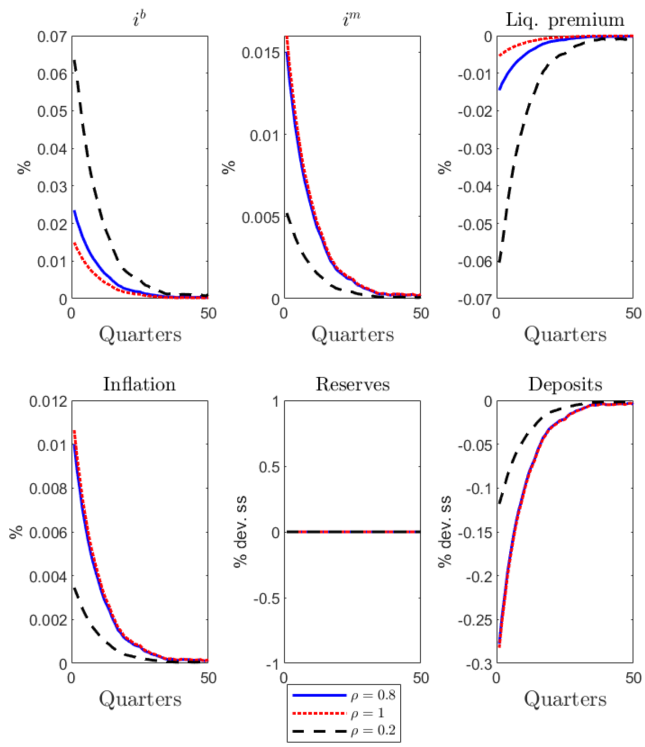
How is monetary policy transmitted to the intertemporal interest rate governing consumption/savings decisions, $i_t$? An increase in the IOR (without a change in the supply of reserves and therefore on $d_t$ on the left-hand side of (10)) increases the interest the central bank pays to banks, and banks fully pass-through this higher rate to the yield they pay on deposits to households. In turn, the increase in the IOR leads to a decrease in inflation, which increases the *real* supply of liquid assets. The marginal convenience service of deposits (the left-hand side of (10)) decreases, and, therefore, the intertemporal rate on the consumption's Euler equation, $i_t$, increases (but by less than the increase in the IOR).

**Definition**: An equilibrium in this economy are prices $\{i_t, i_t^b, i_t^m, A_t, \Pi_t\}$ and policy rules $\{C_t, d_t, l_t, b_t^h, d_t^s, b_t^s, l_t^s\}$ such that:

1. Given prices, households maximize lifetime utility, banks maximize future cash flows,
2. All markets clear: $k_t = 1$, $D_t = D_t^s$, $L_t = L_t^s$, $B_t^h = B_t^s$.

I solve the model using the global nonlinear method in Cao et al. (2023). The remainder of the paper has a predominantly qualitative goal: to show how fiscal and monetary policy interact in the determination of the liquidity value of government debt. The model is too simple to give a full quantitative characterization of the New Zealand economy. However, to make sure that the analysis comes from reasonable values of the parameters, I calibrate the model to match the debt and reserves levels and the liquidity premium of New Zealand's assets (see the Appendix).

Figure 3: Positive debt supply shock - floor system




# 4 Monetary and fiscal policy interactions

## 4.1 Shock to the supply of debt

First, I consider an exogenous increase in the deficit financed by an increase in the supply of government debt. In New Zealand data, annual growth rate of the supply of T-bills between January 2008 and February 2020 has a mean of 6.25% and a standard deviation of 79. This large standard deviation is influenced by the debt issuance in response to the global financial crisis. I consider an increase in $\zeta_t$ of 1% over a year. The blue line in Figure 3 compares the impulse responses of the yield on T-bills, the liquidity premium, inflation, and central bank reserves for a value of $\rho = 0.8$.

When the government issues new debt, current inflation rises and the monetary policy rule calls for a rise in $i_t^m$. Notice that the rise in $i_t^m$ does not imply a decrease in the supply of reserves, which is the main feature of the floor system. The liquidity premium on government debt falls, because the increase in real supply is not fully offset by the increase in inflation.

Alternatively, the impulse responses in Figure 3 can be given an interpretation from a liquidity preference perspective. By raising $i_t^m$, the central bank is lowering the cost of liquidity of households to encourage them to hold the new debt. This is achieved through an increase in the interest on reserves, which banks pass onto the yield they pay on deposits. This will reduce the cost of liquidity for all liquid assets in the economy, including T-bills. The final effect is a drop in the liquidity premium, coming both from the direct effect of extra supply of debt and the indirect effect of the higher interest on reserves. The supply of deposits falls because loans supply decreases, but the magnitude of this drop is small enough to not change the response of the liquidity premium.

Under a corridor system, the central bank would also raise the interest rate, but this would need a reduction in reserves and a much larger drop in the supply of deposits. This drop in the supply of deposits would offset the increase in debt supply; if they are perfect substitutes, then there would be no change in overall liquidity and no change in the liquidity premium. This is how Nagel (2016) explains that in his regressions the supply of debt has no statistical significance. Notice, however, that this mechanism predicts a negative correlation between debt and reserves, which does not fit the data.

Figure 3 also shows the responses for different degrees of substitutability between deposits and T-bills. I plot the responses for $\rho = 0.2$ (low substitutability between deposits and T-bills) and $\rho = 1$ (perfect substitutability) along with $\rho = 0.8$. In line with intuition, the rise in inflation is higher when the degree of substitutability is higher: the more T-bills can be used for money-like transactions, new issuance by the government will have a larger impact on inflation. Accordingly, the rise in the IOR needed to counteract this shock is higher for higher values of $\rho$. At the same time, when bonds and deposits are imperfect substitutes ($\rho = 0.2$), the impact of the shock on inflation and the IOR is lower, but on the other hand the impact on the liquidity premium is higher.

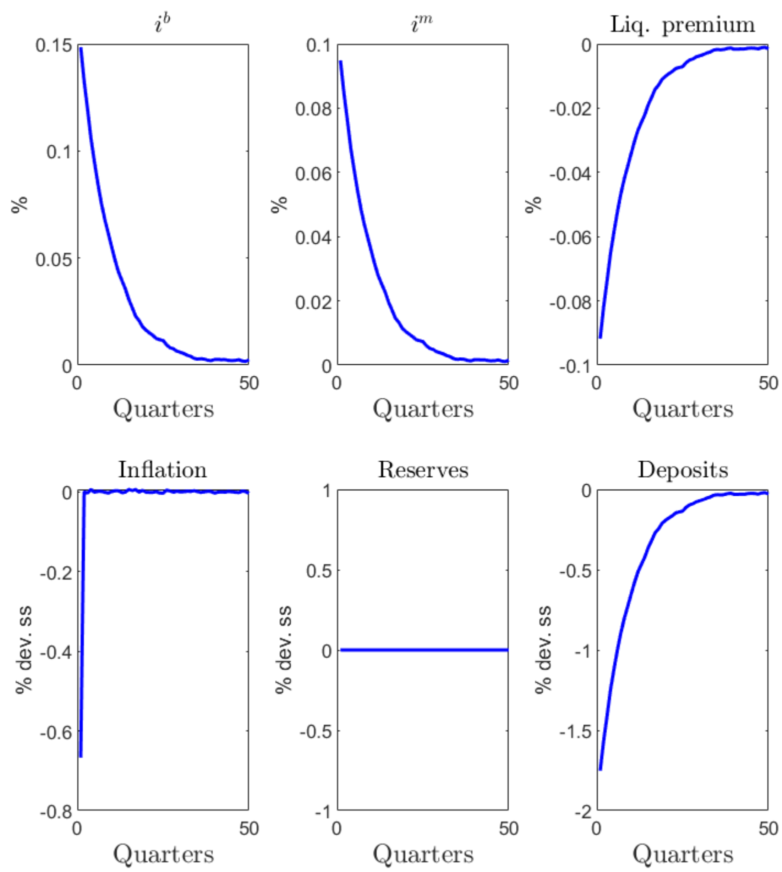
Another purpose of Figure 3 is to show that, under a floor system, the supply of debt has a causal impact on the liquidity premium regardless of the degree of substitutability between deposits and bonds. Vandeweyer (2021) extends the regressions in Nagel (2016) and finds that the supply of debt has become statistically significant in the United States after 2008. This leads him to conclude that it must be because deposits and T-bills are no longer perfect substitutes. Figure 3 shows that debt becoming statistically significant once the United States transitioned to an abundant-reserve system cannot be used to conclude on the degree of substitutability between T-bills and deposits.

## 4.2 Monetary Policy Shock

In this subsection I consider a positive realization of $\xi_t$ in the Taylor rule (21). The monetary policy shock in the model is assumed to follow an iid process. The 25 basis point shock increases the interest paid on reserves, with everything else being equal, by 1% at annual rates. In Figure 4 I set the parameter $\rho$ at 0.8, reflecting a high degree of substitutability.

In the current model of a floor system, the positive realization of $\xi_t$ lowers current inflation and raises the interest on reserves. The lower inflation increases the real value of government debt, and therefore it reduces the marginal value of liquidity. At the same time, the higher IOR increases the

Figure 4: Monetary Policy Tightening - Floor System




yield earned by banks on holding reserves, which they pass-through to a higher yield on deposits. This lowers the cost of liquidity for households and, therefore, their willingness to pay for the liquidity provided by T-bills. The combined effect of these two forces lowers the liquidity premium on T-bills, as shown in Figure 4.

Before I turn to the policy implications, I run the model assuming the Central Bank implements a corridor system. This helps to validate the model by showing that it does not only work for a floor system. In particular, it shows that the model under a corridor system is able to match the positive correlation between the interbank rate and the liquidity premium (as found in Nagel, 2016), and the positive correlation between the supply of deposits and the supply of T-bills (as found in Section 2). To perform this exercise, I assume a functional form for $\theta(\frac{l_t}{m_t^d})$, and let it respond to the supply of reserves ($m_t^s < \overline{m}_t$). In addition, I assume that the Central Bank fixes $i_t^m = 0$, and therefore there is a one-to-one relationship between the supply of reserves and $i_t^d$.

Table 2 shows the relevant correlations among the variables. Since this is not a quantitative exercise, I pay attention to the sign and significance of the values more than in their magnitude.

Notice that both the supply of deposits and the supply of T-bills positively correlate with the cycle. Facing a positive realization of the endowment process, under a corridor system the hike in $i_t^d$ now needs a decrease in the supply of reserves, which reduces the supply of deposits. The increase in current inflation, in turn, decreases the real burden of the government, and the fiscal rule allows for a reduction in the supply of debt. As a result, the overall supply of liquid assets decreases and the liquidity premium increases. Therefore, there is a clear positive correlation between the interbank rate, $i_t^d$, and the liquidity premium, as shown in the last row of Table 2.

Table 2: Second moments under a Corridor System

| Moment | Value |
|---|---|
| corr($Y_t$,$b_t$) | 0.401 |
| corr($Y_t$,$m_t$) | 0.9517 |
| corr($Y_t$,$d_t$) | 0.9603 |
| corr($i_t - i_t^b$,$i_t^d$) | 0.781 |

Note: Values calculated from simulating 50,000 periods and dropping the first 10,000.

### 4.3 Implications for monetary policy transmission

Since both deposits and T-bills carry a convenience yield, the way monetary policy is actually implemented will have implications for monetary policy itself and for fiscal sustainability.

First, I analyze the implications for monetary policy transmission. A feature of the model in Section 3 is that convenience yields drive a wedge between the rate that the central bank controls, and the rate that the central bank wants to affect (the intertemporal rate). Therefore, the transmission from the policy rate to the intertemporal rate will depend on the response of convenience yields. Since the corridor and the floor systems manage liquidity in different ways, they will have different outcomes regarding monetary policy transmission.

**Proposition 1** *In response to endowment shocks along the business cycle, the needed change in the interest on reserves under a floor system, $i_t^m$, is larger in magnitude that the response that would be needed on the interbank rate under a corridor system, $i_t^d$.*

*Proof*: see Appendix.

To see the intuition, consider a good realization of the exogenous endowment process. As the household would prefer to borrow, by the Euler equation on consumption this translates into a rise in the intertemporal rate, $i_t$.

The central bank will accommodate this by an increase in the interbank rate (under a corridor system) or in the interest on reserves (under a floor system). However, the interest on reserves under a floor system will require an increase larger in magnitude. The reason is that, under a corridor system, the increase in the banks' cost of liquidity and the consequent reduction in the supply of deposits helps to accommodate the drop in savings demand of the household.

To see this formally, one can rearrange Equation (10) to get:

$$i_t^d = i_t(1 - v_{dt}) - v_{dt} \tag{22}$$

where $v_{dt} = \frac{\alpha(1-\lambda_t)(\frac{D_t}{P_t})^{\rho-1}}{u_c(C_t)[(1-\lambda_t)(\frac{D_t}{P_t})^{\rho}+\lambda_t(\frac{B_t^h}{P_t})^{\rho}]}$ is the marginal convenience yield of deposits for the household. Under a corridor system, the reduction in the supply of reserves will reduce the supply of deposits, $v_{dt}$ will increase, and the hike needed in $i_t^d$ will be less. Under a floor system, on the other hand, there is no change in the supply of reserves, and therefore the change in $v_{dt}$ is more muted. As a result, $i_t^m$ will need to move closer to one-to-one with the intertemporal rate, $i_t$[2].

As a consequence, under a floor system a central bank will need more "aggressive" policy responses to the business cycle than under a corridor system. A central bank that transitions from a corridor to a floor system and does not take this into account, runs the risk of running inflation persistently above its target.

### 4.4 Implications for fiscal capacity

The model can be used to explore direct implications for the fiscal capacity of the government. Issuing too much debt can potentially exhaust the convenience yield and negatively impact the fiscal capacity of the government. At the same time, an aggressive monetary policy tightening in the form of rises in the interest on reserves can also reduce fiscal capacity via the same channel.

To see this, take the government's budget constraint in (19), ignoring for now the role of reserves as a liability for the government. Iterate it forward, and impose the transversality condition $\lim_{n\to\infty} E_t[q_{t,t+n}b_{t,t+n}] = 0$ to get:

$$b_t = \lim_{n\to\infty}\sum_{j=1}^{n} q_{t,t+j}s_{t+j} + \lim_{n\to\infty}\sum_{j=1}^{n} q_{t,t+j}(i_t - i_t^b)b_t \tag{23}$$

[2]The implication that the proportional magnitude of the response of $i_t$ is different in a corridor versus a floor system can also be found in the model of Piazzesi et al. (2021).

where $q_{t,t+j} = \mathbb{E}[\beta^j (u'(C_{t+j})/u'(C_t))]$ is the model-based stochastic discount factor. The left-hand side in Equation (23) corresponds to the current debt-to-GDP ratio (recall that mean endowment has been normalized to one). The first term on the right-hand side is the discounted present value of future primary surpluses. The second term is the discounted present value of future liquidity services.

What Equation (23) shows is that the fiscal capacity of the government increases when government debt provides safety and liquidity services to investors: the current value of debt-to-GDP can be above the present discounted value of primary surpluses thanks to the second term on the right hand side, which depends on the magnitude of the liquidity premium, $i_t - i_t^b$. This term is what Reis (2022) calls the "debt revenue" term. Fiscal capacity analysis for the U.S. in Mian et al. (2022) and Jiang et al. (2022a) assumes the debt revenue term depends negatively on the supply of debt.

Equation (23) can be used to give an idea of the economic magnitude of the convenience yield in New Zealand's data. An average liquidity premium of 1.2% over the period coupled with a mean debt-to-GDP ratio of 0.42 gives a flow debt revenue of 0.5% of GDP. Discounting at the mean illiquid rate of 2.44% (4.44% nominal rate minus 2% inflation), and ignoring risk or uncertainty in calculating the present value over a long time horizon, implies that debt revenue can sustain $0.5/0.024 = 20.8\%$ of GDP in public debt. This number is lower than the ones obtained by Reis (2022) for the U.S. and other G7 countries.

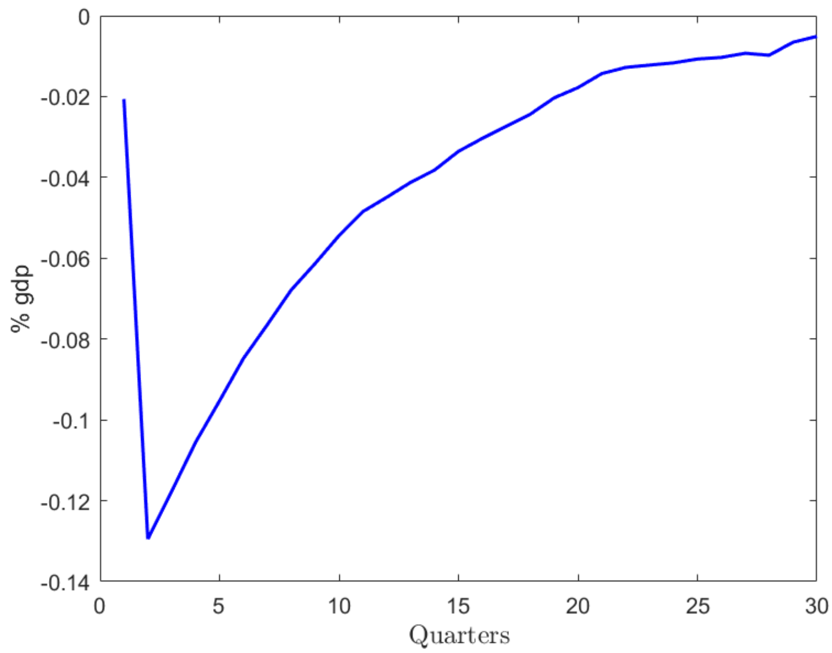
A few caveats to this magnitude. First, of course, it assumes that all debt is short-term and therefore enjoys the convenience yield of T-bills. A more complete analysis would take into account debt at different maturities and consider that longer maturities are less money-like than T-bills. Second, it does not take into account central bank reserves as a potential debt obligation for the Treasury.

What is the impact of monetary policy on the fiscal capacity of the government? In the model, a monetary policy shock increases the debt burden of the government in real terms, which increases borrowing and reduces deficits going forward (per the fiscal rule in (20)). This impact is qualitatively the same regardless of how monetary policy is conducted.

The floor system will have a distinct negative impact on the "debt revenue" term in (23). Figure 5 below shows the response of the "debt revenue" term to the same monetary policy shock analyzed in Section 4.2. The fiscal capacity of the government drops along with the debt revenue term. There is a sharp decrease on impact during the first two quarters as the drop in inflation raises real rates. After that effect, fiscal capacity recovers only slowly because of the slow dynamics of the liquidity premium.

This result can bring new insights to the current sharp tightening cycle on which central banks of advanced economies are embarked since early 2022. This tightening has coincided with high levels of debt-to-GDP as a consequence of the fiscal response to the Covid-19 crisis. Although more

Figure 5: IRF of Debt Revenue to a Monetary Policy Shock




research is needed, it might be a relevant element in the discussion on the optimal size of the central bank's balance sheet.

## 5 Conclusions

This paper has shown that both fiscal and monetary policy interact in determining the near-money properties of government debt. Contrary to previous results in the literature, I have shown that the supply of government debt negatively impacts its liquidity premium. I have isolated this effect when a central bank operates under a floor system, and it does not need to alter the supply of reserves to hit its rate target. This clears the confounding factor of the supply of reserves and allows me to isolate the causal impact of the supply of government debt. The main implication of this result is that a government that borrows too much can reduce the premium and eventually exhaust it. From the perspective of fiscal policy, too much borrowing can reduce the debt revenue term in the government's budget constraint, which confirms previous assumptions that a government cannot indefinitely exploit the seignorage revenue coming from the safety/liquidity of irs debt (Mian et al., 2021; Reis, 2021).

At the same time, the floor system allows one to estimate the impact of interest rates, stripped of their links to the supply of central bank reserves. This has provided new insights on the interaction of the short-end of government bonds with monetary policy. The positive correlation between the monetary policy rate and the liquidity premium likely reverses under a floor system. This has implications for monetary policy transmission because the illiquid rate is less responsive to the stance of monetary policy compared to when a corridor system is implemented. At the same time, this implies that increases in the monetary policy rate can have further negative effects on the fiscal capacity of the government. As the number of advanced economies implementing an abundant-reserves system has grown in the past decade, it is even more critical to understand how this new system has changed this and other linkages between monetary and fiscal policy. One fruitful avenue for future research will be to take into account the endogenous debt maturity decisions by the fiscal authority.

## References

Afonso, Gara, Kyungmin Kim, Antoine Martin, Ed Nosal, Simon Potter, and Sam Schulhofer-Wohl, 2020. "Monetary Policy Implementation with an Ample Supply of Reserves", Finance and Economics Division Series 2020-020. Washington: Board of Governors of the Federal Reserve System.

Arce, Óscar, Galo Nuño, Dominik Thaler, and Carlos Thomas, 2020. "A large central bank balance sheet? Floor vs corridor systems in a New Keynesian environment", *Journal of Monetary Economics* 114, 350-67.

Benigno, Gianluca and Pierpaolo Benigno, 2021. "Interest, Reserves and Prices",`https://www.newyorkfed.org/research/staff_reports/sr971` Accesed on 2021-07-15.

Bohn, Henning, 1998. "The Behavior of U.S. Public Debt and Deficits", *Quarterly Journal of Economics* 113(3): 949-963.

Canzoneri, Matthew, and Behzad Diba, 2005. "Interest rate rules and price determinacy: The role of transactions services of bonds", *Journal of Monetary Economics* 52, 329-343.

Canzoneri, Matthew, Robert Cumby and Behzad Diba, 2017. "Should the Federal Reserve Pay Competitive Interest on Reserves?", *Journal of Money, Credit and Banking* 49(4), 663-693.

Cochrane, John, 2014, "Monetary policy with interest on reserves", *Journal of Economic Dynamics & Control* 49, 74-108.

Cochrane, John, 2023. "The Fiscal Theory of the Price Level", Princeton University Press.

Cúrdia, Vasco and Michael Woodford, 2011, "The central bank balance sheet as an instrument of monetary policy", *Journal of Monetary Economics* 58 (1), 54-79.

Del Negro, Marco, Gauti Eggertsson, Andrea Ferrero and Nobuhiro Kiyotaki, 2017. "The Great Escape? A Quantitative Evaluation of the Fed's Liquidity Facilities", *American Economic Review*, 107(3), 824-857.

Greenwood, Robin, and Dimitri Vayanos, 2010. "Price pressure in the government bond market", *American Economic Review: Papers and Proceedings* 100(2), 585-590.

______, 2014. "Bond supply and excess bond returns", *Review of Financial Studies* 27(3) 663-713.

Greenwood, Robin, Sam Hanson and Jeremy Stein, 2015, "A comparative-advantage approach to government debt maturity", *Journal of Finance* 70, 1683-1722.

Hanson, Samuel, and Jeremy Stein, 2015. "Monetary policy and long-term real rates", *Journal of Financial Economics* 115, 429-448.

Jiang, Zhengyang, Hanno Lustig, Stijn van Nieuwerburgh and Mindy Xiaolan, 2022a. "Measuring U.S. Fiscal Capacity Using Discounted Cash Flows Analysis", *Brookings Papers on Economic Activity*, Fall.

______, 2022b. "The US Public Debt Valuation Puzzle". Available at SSRN: `https://ssrn.com/abstract=3333517`.

Krishnamurthy, Arvind and Annette Vissing-Jorgensen, 2011. “The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy”, *Brookings Papers on Economic Activity*, Fall, 215-287.

______, 2012, “The aggregate demand for Treasury Debt”, *Journal of Political Economy* 120, 233-267.

______, 2015, “The impact of Treasury supply on financial sector lending and stability”, *Journal of Financial Economics* 118, 571-600.

Lenel, Moritz, Monika Piazzesi and Martin Schneider, 2019, “The short rate disconnect in a monetary economy”, *Journal of Monetary Economics* 106, 59-77.

Mian, Atif, Amir Sufi and Ludwig Straub, 2021. “A Goldilocks Theory of Fiscal Policy”, NBER Working Paper 29707.

Nagel, Stefan, 2016, “The liquidity premium of near-money assets”, *Quarterly Journal of Economics* 131, 1927-1971.

Piazzesi, Monika, Ciaran Rogers and Martin Schneider, 2021, “Money and banking in a New Keynesian Model”, `https://web.stanford.edu/~piazzesi/MBinNK.pdf`. Accesed on 2021-03-29.

Piazzesi, Monika and Eric Swanson, 2008. “Futures Prices as Risk-Adjusted Forecasts of Monetary Policy”, *Journal of Monetary Economics* 55, 677-691.

Poole, William, 1968. “Commercial Bank Reserve Management in a Stochastic Model: Implications for Monetary Policy”, *Journal of Finance* 23(5), 769-791.

Reis, Ricardo, 2021. “The constraint on public debt when $r < g$ but $g < m$”, `https://ideas.repec.org/p/cpr/ceprdp/15950.html`. Accesed on 2022-07-27.

Vandeweyer, Quentin, 2021. “Treasury Debt and the Pricing of Short-Term Assets”, `https://faculty.chicagobooth.edu/-/media/faculty/quentin-vandeweyer/papers/t-bill_shortage_jan2022.pdf`. Accesed on 2021-08-21.

Vayanos, Dimitri, and Jean-Luc Vila, 2021. “A Preferred-Habitat Model of the Term Structure of Interest Rates”, *Econometrica* 89, 77-112.

## Appendix A Data sources

**Yields**: the interest on reserves, the 3-month bank bill rate, and the 6-month term deposit rate are from the Reserve Bank of New Zealand (RBNZ) statistics. See Wholesale interest rates, table B2 monthly, for the OCR and the bank bill, and Retail interest rates, table B3, for the term deposit rate. The 3- and 6-months yields on T-bills are calculated from auction results published by the Debt Management Office of the New Zealand's Treasury. When there is more than one instrument offered, I take the weighted average of successful yields.

**Supply of T-bills and deposits**: the amount of T-bills outstanding are published at the monthly frequency by the Debt Management Office of the New Zealand's Treasury. Series are at market value. The supply of reserves by the central bank is obtained from the RBNZ's balance sheet (see statistics, table R2). The two proxies for the supply of deposits correspond to households' deposits at registered banks, available at the RBNZ's statistics (see Household balance sheet, table C22); and total deposits calculated as broad money minus currency in circulation (from the RBNZ's balance sheet).

All these variables are scaled by GDP, which it is available at FRED (current price Gross Domestic Product in New Zealand, New Zealand dollars, Quarterly). The series was brought to monthly frequency through interpolation.

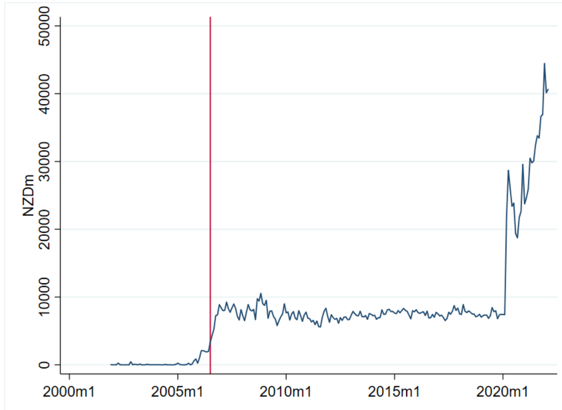
**Other**: the VIX index and the U.S. federal funds rate were obtained from FRED (series VIXCLS and EFFR). Data for bank bills' futures contracts prices (the instrumental variable for the IOR) was obtained from Bloomberg, tickers ZB1 and ZB2. Supply for U.S. T-bills (see Figure 1 in the main text) was obtained from Treasurydirect. U.S. deposit supply in the same Figure corresponds to the sum of checking and savings accounts in Table 4 in H.6 release (see FRED).

## Appendix B Monetary policy in New Zealand

This section relies on Keister et al. (2008) and Selgin (2018) to describe New Zealand's transition to a floor system. From 1999 until July 2006, the Reserve Bank of New Zealand (RBNZ) implemented a symmetric corridor system in which the benchmark policy rate, the Official Cash Rate (OCR), was kept 25 basis points above the rate paid on reserves and 25 points below what was charged for overnight loans. Because in such a regime banks' overnight settlement balances (i.e., reserves) bore an opportunity cost, banks held very few such balances, relying instead on intraday credits from the RBNZ to meet their ongoing settlement needs.

Along with its corridor system, the RBNZ implemented a Real Time Gross Settlement (RTGS) system for wholesale payments, in which interbank payments are settled bilaterally and immediately, thereby becoming final and irrevocable as transactions are processed, rather than at the end of the business day only. This allows payments to be made final as soon as they are processed. If

Figure 6: Reserve supply in New Zealand




in the remainder of the day a bank faced any real-time liquidity need, it would rely on credit from the RBNZ instead of waiting to settle their net balances at the end of each day.

The disadvantage of the RTGS is that it exposed the central bank to credit risk. To avoid that risk the RBNZ chose to supply intraday credit through fully secured reverse repo agreements. However, the Government of New Zealand had been running a fiscal surplus for a few years and government bonds had become scarce. Since these bonds were the preferred collateral, the scarcity produced wide volatility in the interbank market and often resulted in rates significantly above the target desired to implement monetary policy. The RBNZ had to accept municipal and corporate paper as collateral, which did not fully eliminate risk of losses.

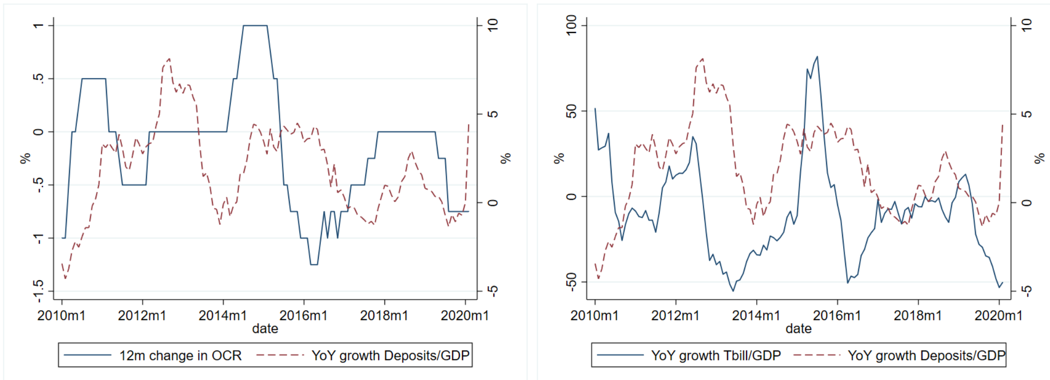
The RBNZ conducted a review of its liquidity management regime in 2005 and announced a new system in early 2006. Recognizing the danger of losses, the RBNZ encouraged banks to rely on overnight settlement balances (reserves), instead of intraday repos, to meet their settlement needs. With that end in mind, in July 2006 the RBNZ began its program of "cashing up" the banking system. The first step was to create an additional NZ$7 billion in reserves between July and October. Concurrently, it increased the interest paid on those reserves in 25 basis points (made in five-points increments), to encourage banks to hold them. Next, the RBNZ stopped providing intraday repos. At the end, the RBNZ achieved the two key components of a floor system: the interest rate on reserves was set equal to the policy rate and banks were well supplied, if not satiated, with liquidity.

Figure 6 plots the evolution of the supply of reserves. The vertical red line marks the official start of the floor system. The level of reserves went from a negligible amount (NZ$20 million approx.) to around NZ$8 billion. This level was kept steady until March 2020, when QE raised the supply to almost NZ$30 billion.

Figure 7 suggests that deposit supply is no longer endogenous to monetary policy under a floor system. Banks hold enough reserves, and the liquidity cost of creating new deposits no longer

Figure 7: Correlations for NZ: Jul. 2006 - Feb. 2020

(a) Interest on reserves and deposit supply (b) T-bills and deposit supply



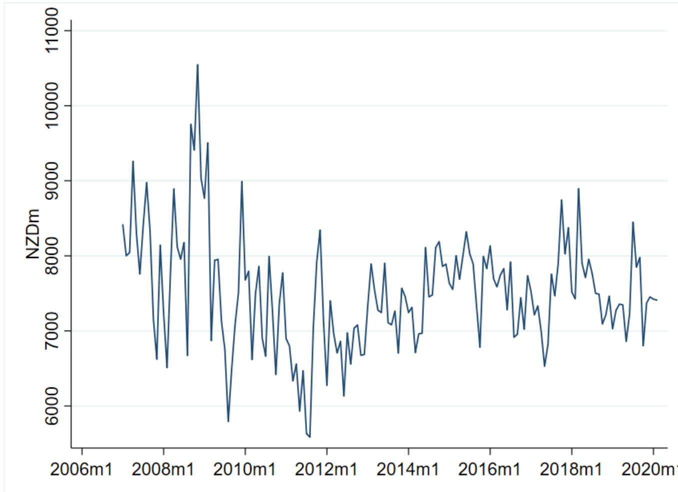

depends on the availability of reserves. In Figure 7a the correlation between the interest on reserves and the supply of deposits is not significant. Under a corridor system like the one in the United States before 2008, this correlation would be significantly negative. In Figure 7b the correlation between T-bills and deposits is also not significantly different from zero, showing the disconnection between the two under a floor system.

Can we be sure to rule out any endogenous variation in reserve supply? There are two episodes in which the RBNZ injected further liquidity into the banking system, both during the financial turmoil of 2008 (in August 2007 and in the Fall of 2009). These are the most likely to be driven by liquidity concerns and thus be endogenous. Figure 8 provides a closer inspection for the evolution of reserve supply. Although the RBNZ occasionally found it desirable to inject some extra reserves into the banking system -as in the two episodes mentioned- those cash additions were modest and transitory. As an extra precaution, I add the supply of reserves or deposits in the regressions, in order to control for any out-of-order variation in their quantities.

Finally, one important reform happened in August 2007. A common issue with supplying too many reserves is that banks no longer need to rely on one another to access reserves, effectively ending active trading in the interbank market. This is what has happened in the US since 2008 in the federal funds market, were the number of transactions has been at a minimum for the past decade. The RBNZ concluded that it was a good idea to avoid this outcome, as an active interbank market provides information on the health of the banks. However, once the floor system was up and running it became clear that it was encouraging at least some banks to hoard reserves, accumulating them without incurring any opportunity cost and thus without the need to go to the interbank market.

The solution to the reserve hoarding problem was a “tiering system”, with reserves up to a bank’s assigned tier limit earning the interest on reserves, and reserves beyond that level earning 100 basis points less. The tier levels were themselves based on banks’ apparent settlement needs,

Figure 8: Reserve supply in New Zealand: Jul. 2006 - Feb. 2020




but collectively still amounting to the aggregate target of NZ$7 billion. Thanks to this switch to a tiered system, the overnight interbank lending market remained active. Banks continued to rely upon one another as lenders of first resort, turning to the RBNZ for overnight funds only as a last resort.

It is important to notice that this tiered system does not affect my identification strategy. Even though an active interbank market might suggest that banks are not fully satiated with liquidity, my strategy only needs that the overall supply of reserves is not correlated with the monetary policy rate, as they actually are in a scarce-reserve system. Figure 7 shows that this is the case. In contrast, the same graph for a corridor system -like the one in the US before 2008- would show a significant negative correlation between the federal funds rate and the supply of reserves/deposits.

# Appendix C Robustness for results in section 2

Table 4 estimates equation (4) with data for New Zealand, from July 2006 until July 2021. The dependent variable is the spread between the 3-month bank bill and the 3-month T-bill. To avoid concerns with stochastic trends I difference both the dependent and the independent variables. This avoids spurious correlation between the levels of these variables by removing random walk components in these series. All columns are estimated using OLS, with the standard errors adjusted for autocorrelation using the Newey West estimator.

In Column 1 the coefficient on the supply of T-bills is negative and significant. A one percent increase in T-bills to GDP reduces the liquidity premium in 28 basis points. The coefficient on the IOR is negative, although not statistically significant. Column 2 adds the supply of reserves as a percentage of GDP, which serves as a robustness check to the intuition that under a floor system reserves supply are exogenous in the determination of the liquidity premium. The estimation shows

Table 3: New Zealand: Determinants of liquidity premium - OLS

| | Sample: 2006m7-2021m7 | | | | Sample: 2006m7-2020m2 | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $\Delta ior_t$ | -0.0826 | -0.0835 | -0.187*** | -0.187*** | -0.0941* | -0.101* | -0.206*** | -0.227*** |
| | (0.0520) | (0.0529) | (0.0629) | (0.0630) | (0.0558) | (0.0542) | (0.0685) | (0.0697) |
| $\Delta ior_{t-1}$ | | | 0.265*** | 0.269*** | | | 0.273*** | 0.295*** |
| | | | (0.0763) | (0.0749) | | | (0.0774) | (0.0812) |
| $\Delta vix_t$ | 0.00352*** | 0.00256 | 0.00157 | 0.000450 | 0.00477** | 0.00459** | 0.00353 | 0.00370* |
| | (0.00133) | (0.00166) | (0.00149) | (0.00203) | (0.00193) | (0.00175) | (0.00216) | (0.00203) |
| $\Delta vix_{t-1}$ | | | 0.00134 | 0.000670 | | | -0.000563 | -0.000823 |
| | | | (0.00449) | (0.00480) | | | (0.00641) | (0.00629) |
| $\Delta\log(\frac{Tbill}{GDP})_t$ | -0.278** | -0.290** | -0.193** | -0.195** | -0.371** | -0.349* | -0.299** | -0.284*** |
| | (0.124) | (0.119) | (0.0922) | (0.0767) | (0.188) | (0.184) | (0.117) | (0.108) |
| $\Delta\log(\frac{Tbill}{GDP})_{t-1}$ | | | -0.0475 | -0.0419 | | | -0.0676 | -0.0538 |
| | | | (0.0901) | (0.0885) | | | (0.119) | (0.109) |
| $\Delta\log(\frac{Res}{GDP})_t$ | | 0.119 | | 0.139 | | 0.180 | | 0.218 |
| | | (0.0855) | | (0.114) | | (0.135) | | (0.145) |
| $\Delta\log(\frac{Res}{GDP})_{t-1}$ | | | | -0.00894 | | | | -0.129 |
| | | | | (0.0795) | | | | (0.0927) |
| Constant | -0.00646 | -0.00786 | -0.000266 | -0.00158 | -0.00864 | -0.00947 | -0.00253 | -0.00259 |
| | (0.00810) | (0.00833) | (0.00599) | (0.00624) | (0.0101) | (0.0103) | (0.00716) | (0.00704) |
| Observations | 181 | 181 | 181 | 181 | 164 | 164 | 164 | 164 |

Notes: Newey-West standard errors in parentheses (6 lags). Units are hundreds of basis points. Dependent variable is the first difference of the 3-month Bank bill/T-bill spread. Independent variables are the same as in Table 1 in the main text.

that it does not have a significant effect, and the coefficient on the supply of T-bills is similar in magnitude and significance.

In columns 3 and 4 I add the current and lagged values of the independent variables. I do this to consider the possibility that the coefficients in columns 1 and 2 are only capturing a transitory effect on the liquidity premium. This is especially relevant in this case where I am using 1-month differences. It can be the case, for example, that new debt issuance by the government has a short-lived impact that fades away soon after (this is in fact what Nagel (2016) find for the supply variable in the US). Results show that the supply of T-bills still has a negative and significant impact, although of smaller magnitude. Importantly, and unlike the results in Nagel (2016), the lagged value is not significant, suggesting it has a more persistent effect. The results for the IOR are the opposite. The current value of the IOR has a significant negative impact that almost fully reverts in the following month. The negative effect of the IOR and its transitory nature is the opposite result as the one in Nagel (2016).

In columns 5-8 I replicate the first four columns but with the sample ending in February 2020. Recall that the RBNZ embarked in large scale asset purchases after March 2020. Large scale asset purchases involve the purchase of assets in exchange of newly issued reserves. Therefore, in this situation we should not expect the supply of reserves to be exogenous anymore. The estimation in columns 5-8 serves as a robustness check as it should be free of any effect of QE and the possible endogeneity of the supply of reserves. The results show that the effects of the supply of T-bills and the IOR are still significant.

## Appendix D Regressions with U.S. data after 2008

Is the negative effect of the interest on reserves robust to using data for other countries? The following Table shows regressions of the liquidity premium for the U.S. after November 2008. The dependent variable is the spread of 3-month AA financial commercial paper and 3-month T-bills. Data for T-bill and reserve supply are from Treasurydirect and FRED, respectively. The caveats pointed out in the main text still apply: mainly, that the supply of reserves is likely to be endogenous to the different QE programs carried out by the Federal Reserve between 2009-2014. However, it is interesting to see the coefficients for the IOR and the supply of T-bills are of the same sign as in Table 4. In particular, both the interest on reserves and the supply of T-bills have a negative effect on the liquidity premium. These results are robust to using IVs (not shown).

## Appendix E Calibration of the Model

The model is calibrated with data for New Zealand at quarterly frequency, using the sample 2006:III to 2021:III. Panel A of Table 5 shows the parameters calibrated externally. I pick a value of risk aversion of 1.5, and assume a Taylor rule parameter for inflation of 1.5, as it is common in the literature.

The rest of the parameters are calibrated under a deterministic steady state. Table 5, Panel B, shows the values for the five parameters. The targets are the illiquid rate, for which I use the yield on 6-month term deposits, the average yield on T-bills, and the OCR during the sample period. I complement this with two quantities: government debt and banking deposits. I define a supply of government debt to GDP of 0.42 (OECD data, General Government debt) and for deposits I set reserves to GDP at 0.12 and other assets to GDP at 1.4. The ratio of reserves to GDP is obtained from the RBNZ and the supply of other assets matches domestic credit by the banking sector from OECD statistics.

The calibration exercise gives a discount factor of 0.994, which is somewhat lower than usual. However, this difference accounts for the illiquidity of the intertemporal rate in the model. The liquidity preference in the household's utility function, $\alpha$, takes the value of 9.617e-04, and the

Table 4: U.S.: Determinants of liquidity premium, 2008m11-2020m6 - OLS

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| $\Delta$ioer$_t$ | -0.363*** | -0.604*** | -0.361** | -0.511*** |
| | (0.124) | (0.158) | (0.157) | (0.124) |
| $\Delta$ioer$_{t-1}$ | | | 0.449*** | 0.403*** |
| | | | (0.131) | (0.103) |
| $\Delta$vix$_t$ | 0.0131*** | 0.0119*** | 0.0113*** | 0.00813*** |
| | (0.00293) | (0.00246) | (0.00284) | (0.00198) |
| $\Delta$vix$_{t-1}$ | | | 0.00561*** | 0.00453** |
| | | | (0.00184) | (0.00181) |
| $\Delta\log(\frac{Tbill}{GDP})_t$ | -0.895*** | -0.755*** | -0.498*** | -0.625*** |
| | (0.223) | (0.195) | (0.139) | (0.154) |
| $\Delta\log(\frac{Tbill}{GDP})_{t-1}$ | | | 0.266 | 0.371*** |
| | | | (0.167) | (0.123) |
| $\Delta\log(\frac{Res}{GDP})_t$ | | -0.932*** | | 0.0747 |
| | | (0.343) | | (0.167) |
| $\Delta\log(\frac{Res}{GDP})_{t-1}$ | | | | -0.495*** |
| | | | | (0.169) |
| Constant | -0.0127 | -0.00209 | -0.00442 | 2.91e-05 |
| | (0.0137) | (0.00935) | (0.00516) | (0.00464) |
| Observations | 140 | 140 | 139 | 139 |

Notes: Newey-West standard errors in parentheses (6 lags). Units are hundreds of basis points. Dependent variable is the first difference of the 3-month AA financial commercial paper/T-bill spread.

relative usefulness of government debt, $\lambda$, is equal to 0.4783. This implies that deposits are only slightly more liquid than T-bills.

Table 6 shows how the model matches the targets for prices and quantities. Last row computes the liquidity premium on government debt.

## Appendix F Proof of Proposition 1

Consider the log-linearized version of the model. In what follows, variables under hats represent deviation from steady state and bars represent steady state values. The household's first order condition with respect to deposits can be written as:

Table 5: Calibration

| | A. Externally calibrated | | |
|---|---|---|---|
| | Description | Value | Source |
| $\gamma$ | Risk aversion | 1.5 | Standard |
| $\psi_\pi$ | CB's response function | 1.5 | Standard |
| $\rho_G$ | Gov's deficit | 0.1 | Bohn (1998) |
| | B. Calibrated | | |
| | Description | Value | Target |
| $\beta$ | Discount factor | 0.994 | mean($i_t$) |
| $\alpha$ | Liq. preference | 0.0013 | mean($i_t^b$) |
| $\lambda$ | T-bill preference | 0.4783 | mean($i_t^m$) |
| $\psi$ | CB's response function | 1.0008 | Inflation target |
| $\chi$ | Loans' cost | 7.6831 | Gov debt/GDP |
| $z$ | Gov's deficit | 6.7164e-04 | Reserves/GDP |

Notes:

$$\hat{i}_t^d = \hat{i}_t - \frac{\overline{I}}{\overline{I^d}} \overline{v}_d \hat{v}_{dt} \tag{24}$$

where $I = 1 + i_t$, $I^d = 1 + i_t^d$, and $v_{dt} = \frac{\alpha(1-\lambda_t)(\frac{D_t}{P_t})^{\rho-1}}{u_c(C_t)[(1-\lambda_t)(\frac{D_t}{P_t})^\rho + \lambda_t(\frac{B_t^h}{P_t})^\rho]}$ is the marginal convenience yield of deposits for the household.

The intermporal rate $\hat{i}_t$ responds to the endowment shock as: $\mathbb{E}[\gamma(\hat{y}_t - \hat{y}_{t+1}) + (\hat{i}_t - \hat{\pi}_{t+1})] = 0$. Per Equation (24), the magnitude of the response of $\hat{i}_t^d$ to the same shock will depend on the response of $\hat{v}_{dt}$. The latter, in turn, will depend on the response of the supply of deposits and the supply of government debt.

The evolution of deposits is given by:

$$\hat{d}_t = \frac{\overline{m}}{\overline{dI^d}}(\hat{m}_t - \hat{i}_t^d) + \frac{\overline{Il}}{\overline{I^d d}}(\hat{i}_t + \hat{l}_t - \hat{i}_t^d) \tag{25}$$

Under a corridor system, there is a decrease in the first term on the right-hand side, as the supply of reserves $\hat{m}_t$ drops and the deposit rate increases. This effect is absent under a floor system, where deposits fall only due to the second term on the right-hand side. Therefore, $\hat{v}_{dt}$ will increase by more under a corridor system. By Equation (24) this means that $\hat{i}_t^d$ needs to respond by a lower magnitude.

Table 6: Model moments and Targets (Annualized)

| Variable | Description | Data | Model |
|---|---|---|---|
| $b_t$ | Gov debt/GDP | 0.42 | 0.42 |
| $m_t$ | Reserves/GDP | 0.12 | 0.12 |
| $l_t$ | Loans/GDP | 1.4 | 1.4 |
| $i_t$ | Illiquid rate | 4.44% | 4.44% |
| $i_t^b$ | Debt yield | 3.25% | 3.25% |
| $i_t^m$ | Interest on reserves (OCR) | 3.34% | 3.34% |
| $i_t - i_t^b$ | Liquidity premium | 1.19% | 1.19% |

Notes:

# References


Afonso, Gara, Kyungmin Kim, Antoine Martin, Ed Nosal, Simon Potter, and Sam Schulhofer-Wohl, 2020. "Monetary Policy Implementation with an Ample Supply of Reserves", Finance and Economics Division Series 2020-020. Washington: Board of Governors of the Federal Reserve System.

Cao, Dan, Wenlan Luo and Guangyu Nie, 2023. "Global DSGE Models", *Review of Economic Dynamics*, forthcoming.

Keister, Todd, Antoine Martin, and James McAndrews, 2008. "Divorcing Money from Monetary Policy", FRBNY Economic Policy Review, September 2008.

Nagel, Stefan, 2016, "The liquidity premium of near-money assets", *Quarterly Journal of Economics* 131, 1927-1971.

Poole, William, 1968. "Commercial Bank Reserve Management in a Stochastic Model: Implications for Monetary Policy", *Journal of Finance* 23(5), 769-791.

Selgin, George, 2018. "New Zealand's Floor System Experience", Cato Insititute Blog, `https://www.cato.org/blog/new-zealands-floor-system-experience`.