The Liquidity Premium of Near-Money Assets *

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Abstract

Near-money assets are money substitutes for storing liquidity. As a consequence, the liquidity premium of near-money assets is tied to the opportunity cost of holding money. When money does not bear interest, this opportunity cost is given by the level of short-term interest rates. The time-series behavior of liquidity premia of T-bills and other near-money assets in the US, Canada, and the UK since the 1970s is consistent with this prediction. In the US, for example, the spread between collateralized interbank lending rates and Treasury bills is strongly positively correlated with the level of short-term interest rates. In crises, however, the liquidity premium de-couples from its usual relationship with the short-term interest rate. Introduction of interest on excess reserves (IOR) at central banks lowers the opportunity cost of holding money for banks and could therefore change the relationship between the level of short-term interest rates and liquidity premia. I find little evidence, however, that the introduction of IOR in Canada and the UK had much effect on liquidity premia of Treasury bills, which suggests that the introduction of IOR did not substantially lower the opportunity costs of holding money for non-banks.

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I Introduction

Prices of highly liquid safe assets such as Treasury bills and recently issued "on-the-run" US Treasury Bonds reflect a liquidity premium. Investors are willing to pay a premium for the liquidity service flow provided by these near-money assets. Does this liquidity premium vary over time? If it does, why? Is there a connection to monetary policy? Recently, a lot of attention has been devoted to understanding why liquidity premia rise during times of crises (Longstaff 2004; Vayanos 2004; Brunnermeier 2009; Krishnamurthy 2010; Musto, Nini, and Schwarz (2014)), but not much is known about time-variation in liquidity premia of near-money assets outside of these crisis episodes.

To guide the empirical analysis of these questions, I present a model in which near-money assets serve as money substitutes for storing liquidity. Households hold zero-interest deposits and Treasury bills for liquidity reasons. Deposits and Treasury bills are perfect substitutes, but they have different liquidity multipliers: one unit of deposits provides more liquidity service flow than one unit of Treasury bills. The banking sector supplies these deposits, but requires some reserve holdings at the central bank as a liquidity buffer. In this model, the level of short-term interest rates represents households' opportunity costs of holding money (in the form of deposits). The liquidity premium of Treasury bills is proportional to the opportunity cost of holding money, and hence to the level of short-term interest rates. This prediction is the focus of the empirical analysis in this paper.

Figure 1 illustrates the key empirical finding. The solid line shows the difference between the interest rate on three-month general collateral repurchase agreements (GC repo, a form of collateralized interbank term lending) and the yield on three-month US T-bills. The term loan in the form of GC repo is illiquid, as the money lent is locked in for three months. In contrast, a T-bill investment can easily be liquidated in a deep market. Consistent with this difference in liquidity, the GC repo rate is typically 0.10 to 0.50 percentage points higher than T-bill yields. This yield spread reflects the premium that market participants are willing to pay for the non-pecuniary liquidity benefits provided by T-bills. As the figure shows, there

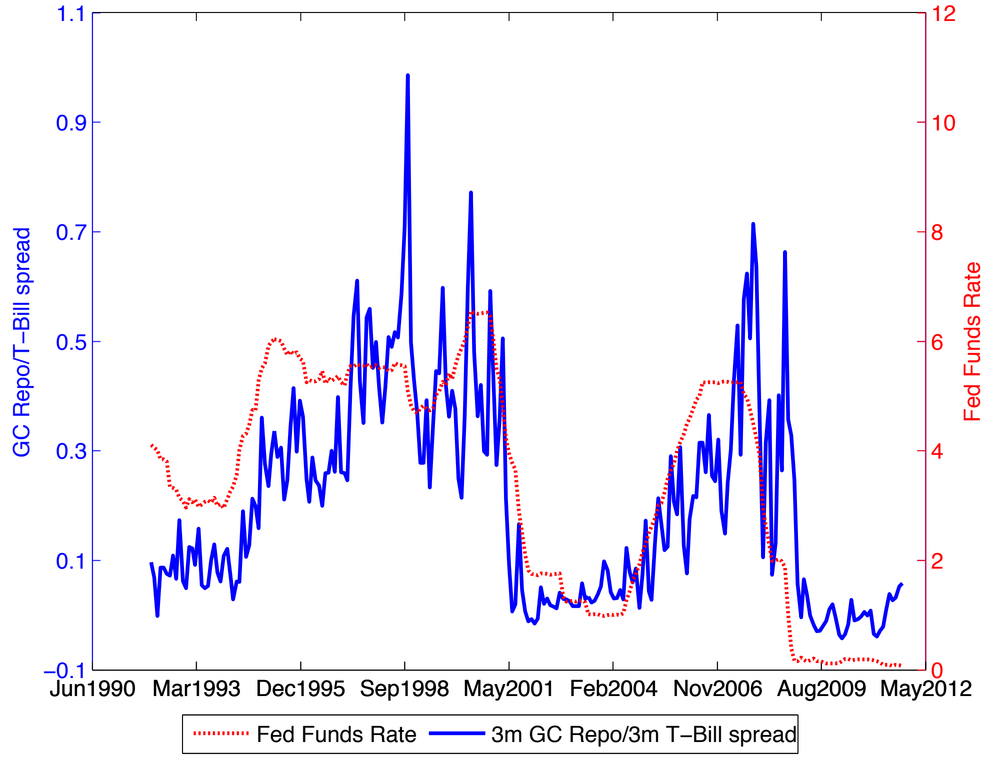

Figure 1: Spread between 3-month Treasury Bill yield and 3-month General Collateral Repo Rate

is substantial variation over time in this liquidity premium. Most importantly, the liquidity premium is closely related to the level of short-term interest rates, represented in the figure by the federal funds rate shown as dotted line. Thus, as the level of short-term interest rates changes, the opportunity cost of holding money changes, and hence the premium that market participants are willing to pay for the liquidity service flow of money substitutes changes as well.

GC repo rates are not available before the early 1990s, but I find that the spread between certificate of deposit (CD) rates and T-bills exhibits a similarly strong positive correlation with the level of short term interest rates in data going back to the 1970s. A similar relationship is also evident in data from Canada and the UK. By comparing US T-bills with yields on discount notes issued by the Federal Home Loan Banks, which have the same tax treatment as T-bills and are guaranteed by the US government, I am further able to rule out that the variation over time in the liquidity premium with the level of interest rates is a tax effect. The spread between illiquid Treasury notes and T-Bills (Amihud and Mendelson 1991) and on-the-run and off-the-run Treasury notes (Krishnamurthy 2002; Warga 1992) also reflects liquidity premia, albeit of a smaller magnitude. I show that these liquidity premia, too, correlate positively with the level of short-term interest rates.

These findings indicate that the opportunity-cost-of-money theory provides a powerful explanation of time-variation in near-money assets' liquidity premia. This insight complements a recent literature that has looked at alternative channels to understand variation in liquidity premia. Bansal, Coleman, and Lundblad (2010), Krishnamurthy and Vissing-Jorgensen (2012a) and Krishnamurthy and Vissing-Jorgensen (2012b) relate slow-moving changes in the supply of US Treasury securities over several decades to the liquidity premium of Treasury securities and to the private sector's supply of liquid assets. Sunderam (2013) focuses on high-frequency (weekly) relations between the liquidity premium and the supply of liquid assets. In his model private-sector short-term debt and T-bills are imperfect substitutes and shocks to liquidity demand affect the liquidity premium, which in turn trigger a short-term debt supply response by the private sector. In my model, liquidity demand and T-bill supply only have effects on liquidity premia to the extent that the central bank allows these shocks to affect the level of short-term interest rates. If the central bank aims to meet an interest-rate operating target, it must elastically absorb these shocks through open-market operations with the consequence that liquidity premia remain unaffected. As long as bank deposits are not impaired in their liquidity service benefits relative to T-bills, shortages of near-money assets that drive up liquidity premia are not possible in this model.

The strong empirical explanatory power of the interest-rate level suggests that this is a useful approach to understand variation in liquidity premia. This does not rule out, of course, that the alternative channels emphasized in these papers could also contribute to time-variation in liquidity premia at higher or lower frequencies than the roughly business-cycle frequency that I focus on. Furthermore, it is clearly apparent that there are instances when the liquidity premium substantially deviates from its normal relationship with the level of short-term interest rates. As Figure 1 shows, during the LTCM crisis in September 1998 and the financial crisis in 2007/08, the liquidity premium of T-bills was elevated relative to the level that one would expect based on short-term interest rates at the time. A plausible explanation for these deviations within my framework is that the liquidity service value of bank deposits is impaired during times of crises. This changes the marginal rate of substitution between deposits and T-bills: T-bills become relatively more valuable as an instrument to store liquidity. As a consequence, market participants are willing to hold T-bills, even if their yield is very low (or perhaps even negative). Decomposition of the Repo/T-bill spread into a component correlated with short-term interest rates and a residual component allows to separate these abnormal shocks to the liquidity premium from the "normal" time-variation induced by changes in interest rates. Only the residual component is positively correlated with the VIX index, a popular crisis indicator.

The degree to which the liquidity premium of near-money moves up and down with the level of short-term interest rates could also depend on the reserve remuneration policies of the central bank. If the central bank starts paying interest on the excess reserves (IOR) that banks hold on deposit, this could lead banks to offer higher, non-zero interest rates even on the most liquid forms of demand deposits. This would reduce households' (and other non-banks') opportunity cost of holding money with the consequence that liquidity premia fall substantially. If the central bank keeps IOR at a fixed spread to the target policy rate, any correlation of liquidity premia with the level of short-term interest could potentially disappear. On the other hand, it is not clear whether the introduction of IOR actually has a significant effect on deposit rates. If interest rates on the most liquid demand deposits remain close to zero, there should be little effect on liquidity premia. My empirical findings are consistent with this latter view. The introduction of IOR in Canada and the UK in 1999 and 2001, respectively, did not lead to a detectable change in the relationship between the

T-bill liquidity premium and short-term interest rates.

The results in this paper also suggest an interpretation of spreads between open-market interest rates and T-bill rates that differs from some earlier interpretations in the literature. Bernanke and Gertler (1995) note that the CD rate/T-bill spread rises during periods of monetary tightening. They interpret this finding as indicative of an imperfectly elastic demand for bank liabilities when banks respond to monetary tightening by looking for non-deposit funding. The findings in this paper suggest an alternative interpretation: Monetary tightening—to the extent that it results in a rise in short-term interest rates—raises the opportunity cost of holding money and the liquidity premium in near-money assets such as T-bills.

Stock and Watson (1989), Bernanke (1990), Friedman and Kuttner (1992) note that the commercial paper (CP)/T-bill spread is a good forecaster of the business cycle. Bernanke and Blinder (1992) show that much of the information about future real activity in the CP/T-bill spread is also captured by the federal funds rate. This finding is consistent with the findings here that spreads like the CP/T-bill spread contain a liquidity premium component that is highly correlated with the level of the federal funds rate. Whether a decomposition of the CP/T-bill spread into the GC repo/T-bill spread (the liquidity premium) and the CP/GC repo spread could improve forecasts of real activity is an interesting open question that is, however, beyond the scope of this paper.

The empirical evidence in this paper is also relevant for applications in which liquidity premia are used as an input to explain other phenomena. For example, Azar, Kagy, and Schmalz (2014) show that changes in the opportunity costs of holding liquid assets in the post-WW II decades can explain variation over time in the level of corporate liquid assets holdings. My findings suggest that the opportunity costs of holding interest-bearing near-money assets are driven by the level of short-term interest rates. Thus, the level of short-term interest rates can be used as a single state variable to model the evolution over time in the opportunity costs of holding liquid assets. This insight is also relevant for the construction of

Divisia monetary aggregates (Barnett 1980; Barnett and Chauvet 2011). In this method, the outstanding stocks of different near-money assets are aggregated and weighted according to their degree of moneyness which is measured by each assets' liquidity premium. My finding that these liquidity premia are strongly positively correlated with the level of short-term interest rates should be useful for modeling the time series of the weights for different types of near-money assets.

The remainder of the paper is organized as follows. Section II presents a model that clarifies the relationship between interest rates and liquidity premia. Empirical evidence on the time-variation in liquidity premia follows in Section III. Section IV examines the effect of reserve remuneration policies of central banks in Canada and the UK. Section V concludes.

II A Model of the Liquidity Premium for Near-Money Assets

I start by setting up a model of an endowment economy in which near-money assets can earn a liquidity premium. The economy is populated by households, and there is a government, comprising the fiscal authority and the central bank. Moreover, there is a banking sector, which is simply a technology to transform loans and reserve holdings into deposits that can be held by households. A key feature of the model is the recognition that money supply and reserve remuneration policies of the central bank can affect the time-series behavior liquidity premia.

A Households

Households derive utility from holding a stock of liquid assets as in Poterba and Rotemberg (1987) (see also, Woodford (2003), Chapter 3). Liquidity services are supplied by government securities and deposits created in the financial sector.

There is a single perishable consumption good, and the representative household seeks to maximize the objective

$$E_0 \sum_{t=1}^{\infty} \beta^t u(C_t, Q_t; \xi_t), \tag{1}$$

subject to the budget constraint

$$W_t = W_{t-1} r_t^W + P_t Y_t - T_t - P_t C_t.$$

where Y_t is the endowment of the consumption good, C_t is consumption, r_t^W is the nominal gross return on wealth, and T_t denotes taxes paid to the government. P_t is the price, in terms of money, of the consumption good. Prices in this economy are flexible and adjust without frictions. Q_t represents an aggregate of liquid asset holdings that provide households with utility from liquidity services and ξ_t is a vector of random shocks that can include preference shocks. For each value of ξ_t, $u(C_t, Q_t; \xi_t)$ is concave and increasing in the first two arguments. I further assume that utility is additively separable in the utility from consumption and utility from liquidity services.

To map the model into the empirical analysis that follows, one can think of one period as lasting roughly a quarter. The liquidity benefits of near-money asset holdings arise from their use in (unmodeled) potentially much higher-frequency transactions, but the indirect utility from these benefits throughout the period enters directly in the utility in (1).

Households can borrow from and lend to each other at a one-period nominal interest rate i_t. Households can also borrow from banks and hold demand deposits, D_t, at banks. Households perceive loans from other households and loans from a bank as perfect substitutes, and hence the interest is the same i_t. Demand deposits with banks are special, however. Unlike loans to other households, deposits with banks provide liquidity services. Treasury bill holdings, B_t, also provide liquidity services to some extent. The T-bills mature in one period and yield i_t^b. The households' total stock of liquidity is a homogeneous-of-degree-one aggregate of the real stock of demandable deposits and T-Bills

$$Q_t = \ell(D_t/P_t, B_t/P_t; \xi_t).$$

Household T-bill holdings do not necessarily have to represent direct holdings. They could also include money market mutual funds that invest in Treasury bills. In contrast, money market mutual funds that invest in private-sector debt claims are better thought of in this model as part of the direct loans from household to household.

The representative household's wealth portfolio is

$$W_t = A_t + B_t + D_t + L_t,$$

where L represents the households' total net loans to other households and banks. A denotes the household's position in assets other than the ones discussed above.

The household first-order conditions with respect to consumption yield the Euler equation

$$1 + i_t = \frac{1}{\beta}\left\{E_t\left[\frac{u_c(C_{t+1};\xi_{t+1})}{u_c(C_t;\xi_t)}\frac{P_t}{P_{t+1}}\right]\right\}^{-1} \tag{2}$$

where u_c denotes the partial derivative with respect to consumption.

The household first-order conditions with respect to real liquid asset balances yield

$$\frac{u_q(Q_t;\xi_t)}{u_c(C_t;\xi_t)}\ell_d(D_t/P_t, B_t/P_t;\xi_t) = \frac{i_t - i_t^d}{1+i_t} \tag{3}$$

$$\frac{u_q(Q_t;\xi_t)}{u_c(C_t;\xi_t)}\ell_b(D_t/P_t, B_t/P_t;\xi_t) = \frac{i_t - i_t^b}{1+i_t} \tag{4}$$

where u_q denotes the partial derivative with respect to Q, and ℓ_d and ℓ_b the partial derivatives of the liquidity aggregate with respect to real balances D_t/P_t and B_t/P_t, respectively. Combining the two equations, we obtain a relationship between the liquidity premium of

T-bills, $i_t - i_t^b$, and the spread between i_t and deposit rates

$$i_t - i_t^b = \frac{\ell_b(D_t/P_t, B_t/P_t; \xi_t)}{\ell_d(D_t/P_t, B_t/P_t; \xi_t)}(i_t - i_t^d) \tag{5}$$

The liquidity premium priced into T-Bill yields needs to be commensurate with the extent to which T-bills provide liquidity services relative to deposits, as captured by the liquidity multipliers ℓ_b and ℓ_d.

B Banks

While households maintain deposit balances for liquidity reasons, banks supply deposits and hold liquidity in the form of reserves M_t. I do not model the banking sector in detail. Instead, I just view it as a technology for transforming liquidity in the form of central bank reserves (which households cannot access) into deposits (which households can access). The banks' assets are invested in loans to the household sector at rate i_t. Any profits flow to households who own the banks.

Two assumptions characterize the banking sector. First, the interest, i_d, paid on demand deposits is zero, unless the central bank pays interest on reserves, i^m. We can write this as

$$i_t^d = \delta(i_t^m), \tag{6}$$

where $\delta(i_t^m)$ is a positive function with $\delta(i_t^m) \leq i_t^m$.[1] To map this assumption to the real world, it is useful to think of interest-bearing deposits and money-market accounts offered by actual financial institutions as packaged portfolios of treasury bills yielding i_t^b, loans yielding i_t, and possibly a demand deposit component. All but the demand deposit component should be thought of, in this model, to reside in the household sector. The real-world counterpart of the demand deposits in this model are the only the most liquid forms of non-interest-bearing deposits.[2] Thus, the banking sector here represents only the part of the actual banking

[1]See Ireland (2012) for a micro-founded version of equation (6)

[2]Driscoll and Judson (2013) report that the average rate on an aggregate of liquid interest-bearing deposits

system that creates highly liquid liabilities.

Second, the relationship between banks' reserve holdings, M_t, and their creation of deposits, D_t^s, is given by

$$D_t^s = \phi(i_t, i_t^m; \xi_t) M_t, \tag{7}$$

where $\phi(i_t, i_t^m; \xi_t)$ is a multiplier that is potentially subject to random shocks. The motivation for this specification is not the usual textbook assumption of reserve requirements, but rather the precautionary need for banks to hold a certain level of liquidity in the form of reserves with the central bank. The multiplier could be microfounded by modeling banks' reserve demand as in Ashcraft, McAndrews, and Skeie (2011) and Bianchi and Bigio (2013). Ashcraft, McAndrews, and Skeie (2011) show that banks hold excess reserves to hedge unexpected payment flows. Even in countries such as Canada or New Zealand, in which legal reserve requirements no longer exist, banks still exhibit a small, but greater than zero demand for reserve holdings (Bowman, Gagnon, and Leahy 2010), even though reserves are remunerated at a rate below the interbank lending rate. The multiplier can depend on i_t and i_t^m, because the magnitude of the spread between i_t and i_t^m may influence the degree to which banks try to economize on holding reserves.

C Government: Fiscal Authority and Central Bank

The government issues liabilities in the form of one-period Treasury bills, B_t^s, through the fiscal authority, and reserves, M_t^s, through the central bank. The central bank pays interest on reserves at a rate $i_t^m < i_t$. I take the path of $\{B_t^s\}$ as exogenous, while $\{M_t^s, i_t^m\}$ is chosen by the central bank to meet an interest-rate operating target i_t^*.

This target could be set, for example, on the basis of a Taylor rule. Alternatively, it could be the path of the interest rate implied by a money growth target. For what follows,

that includes interest-bearing checking accounts, savings deposits, and money-market deposit accounts, is substantially below the federal funds rate, at roughly half of its level. Since this aggregate also includes less liquid savings and money-market deposit accounts, and it excludes non-interest-bearing accounts accounts, the average rate on the most liquid forms of deposits must be even closer to zero.

the precise nature of the central-banks operating procedures is not material. An important aspect of the central banks operating procedures, however, is the level of interest on reserves paid by the central bank i_t^m, where I assume that $i_t^m < i_t$.

The government collects taxes and makes transfers of net amount T_t to satisfy the joint flow budget constraint for government and the central bank consistent with the chosen paths for B_t^s and M_t^s,

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

D Equilibrium

Equilibrium in this model is given by a set of processes $\{P_t, i_t, i_t^b\}$ that that are consistent with household optimization (4), (3), (2), the supply of deposits (7), and market clearing,

$$C_t = Y_t, \quad D_t = D_t^s, \quad M_t = M_t^s, \quad B_t = B_t^s,$$

given the exogenous evolution of $\{Y_t, \xi_t, B_t^s\}$, and processes $\{i_t^m, M_t^s\}$ consistent with the monetary policy rule.

Given the evolution of $\{Y_t, \xi_t\}$, the policy rule for i_t followed by the central bank, together with the Euler equation (2), determines the current price level and expectations of future price levels (see Woodford (2003)). For any targeted i_t^*, given i_t^m, solve (3), with market clearing conditions substituted in,

$$\frac{u_q(Q_t^s;\xi_t)}{u_c(C_t;\xi_t)}\ell_d(\phi(i_t, i_t^m;\xi_t)M_t^s/P_t, B_t^s/P_t;\xi_t) = \frac{i_t - \delta(i_t^m)}{1 + i_t} \tag{8}$$

where $Q_t^s = \ell(M_t^s/P_t, B_t^s/P_t)$, for the M_t^s that the CB must supply to achieve $i_t = i_t^*$. Concerning the conditions under which a solution exists, and the question of determinacy of the price level, see the discussion in Woodford (2003). For the purposes of this analysis, we can assume that the CB's action have resulted in a specific path for i_t and P_t, and ask what these paths imply for liquidity premia.

With market clearing conditions and (7) and (6) substituted into (5), the liquidity premium of Treasury bills can be written as

$$i_t - i_t^b = \frac{\ell_b\left(\phi(i_t, i_t^m; \xi_t) M_t^s / P_t, B_t^s / P_t; \xi_t\right)}{\ell_d\left(\phi(i_t, i_t^m; \xi_t) M_t^s / P_t, B_t^s / P_t; \xi_t\right)} [i_t - \delta(i_t^m)]$$

Thus, time-variation in the liquidity premium is driven by changes in opportunity cost of holding liquidity in the form of deposits, $i_t - \delta(i_t^m)$, and by changes in the relative magnitude of the liquidity multipliers ℓ_b and ℓ_d, i.e., the relative usefulness of T-bills as a store of liquidity compared with deposits. If T-bills become relatively more useful, the ratio ℓ_b/ℓ_d rises, resulting in a lower yield on T-bills and hence greater liquidity premium.

A liquidity demand shock to $u_q(C_t, Q_t; \xi_t)$ has no direct effect on the liquidity premium, because the CB would have to offset the shock by elastically changing the supply of M_t^s (which would change the supply of deposits) to stay at interest-rate target according to (8). There could be an indirect effect, however, if the change in M_t^s causes a change in the ratio of liquidity multipliers ℓ_b/ℓ_d.

Similarly, an elastic reserve supply response of the CB would also offset the effects of a change in the supply of T-bills, with no effect on liquidity premium. This is a key difference of this model to others (e.g., Krishnamurthy and Vissing-Jorgensen 2012b) in which this endogenous liquidity supply response by the CB is not present. The analysis here suggests that a discussion of the supply of liquid assets and the premium for liquidity is incomplete without considering the interplay with monetary policy. In my model, there could again be an indirect effect if the change in B_t^s causes a change in the ratio of liquidity multipliers ℓ_b/ℓ_d. For example, if a shrinking T-bill supply raises the marginal liquidity services of T-bills relative to deposits, the ratio ℓ_b/ℓ_d would rise, resulting in an elevated level of the T-bill liquidity premium. The extent to which changes ℓ_b/ℓ_d matter empirically at the frequencies that I focus on in this paper is an empirical question.

Baseline model. As a working hypothesis, I turn off these indirect effects of money and

T-bill supply by specializing to a linear liquidity aggregator

$$Q_t = \ell_d(\xi_t)(D_t/P_t) + \ell_b(\xi_t)(B_t/P_t),$$

i.e., D and B are perfect substitutes, but with different liquidity multipliers ℓ_d, ℓ_b. The liquidity multipliers in this linear case do not depend on the level of D_t and B_t. As a consequence, the liquidity premium

$$i_t - i_t^b = \frac{\ell_b(\xi_t)}{\ell_d(\xi_t)}[i_t - \delta(i_t^m)] \tag{9}$$

is now completely insensitive to shocks to overall liquidity demand. The empirical analysis below focuses on evaluating this prediction that time-variation in the liquidity premium of T-bills is driven by the time-variation in the opportunity costs of liquidity, $i_t - \delta(i_t^m)$.

Crisis effects. The liquidity premium is still, however, potentially subject to random shocks ξ_t that change the relative magnitudes of the liquidity multipliers of deposits and T-bills. As the empirical analysis shows below, there are big spikes in liquidity premia during times of financial market turmoil. Within this model, one can think of these spikes as the consequence of a shock that destroys "trust" in bank deposits as a store of liquidity, which lowers the liquidity multiplier of deposits ℓ_d relative to ℓ_b.[3] According to (9), this raises the liquidity premium of T-bills. If i_t is sufficiently low, or the shock sufficiently big, this could lead to T-bill yields falling into negative territory.

Interest on reserves. If the CB introduces IOR, $i_t^m > 0$, this could potentially affect liquidity premia if the introduction of IOR affects the rate that banks pay on deposits. It is perceivable that $i_t^d = \delta(i_t^m)$ could rise close to i_t^m if banks aggressively compete for deposits and try to earn the spread $i_t^m - i_t^d$. If so, this would push down liquidity premia. For example, starting from a situation where $i_t^m = 0$ and $i_t^d = 0$, if the introduction of IOR leads to $i^d = i_t^m > 0$, then the liquidity premium in (9) falls from $[\ell_b(\xi_t)/\ell_d(\xi_t)]i_t$ to

[3] As an example for a model in which a crisis shock can impair the liquidity value of bank deposits see Robatto (2013).

$[\ell_b(\xi_t)/\ell_d(\xi_t)](i_t - i_t^m)$. Because central banks that pay IOR typically keep the spread between $i_t - i_t^m$ constant when they change their target for i_t, the liquidity premium in this case would also be constant over time rather than varying with the level of i_t.

The extreme case of $i_t^m = i_t$ corresponds to the "Friedman rule" (Friedman 1960) according to which the payment of $i_t^m = i_t$ (or, alternatively, deflation that results in nominal interest rates of zero) would eliminate the implicit taxation of reserves (see, also, Goodfriend 2002; Cúrdia and Woodford 2011). If, in addition, deposit rates rise to $i_t^d = i_t^m$, then liquidity premia shrink to zero. The payment of market rates as IOR would then not only eliminate the reserves tax, but it would eliminate a liquidity tax more broadly, as T-bills and other highly liquid government liabilities would no longer trade at a liquidity premium.

On the other hand, it is possible that the market for deposits is not sufficiently competitive or that reserves are too small a part of banks assets for IOR to have much effect on deposit rates. Thus, whether or not i_t^d rises towards i_t^m and whether the introduction of IOR shrinks liquidity premia is, in the end, an empirical question.

III Empirical Dynamics of the Liquidity Premium of Near-Money Assets

I now turn to an empirical evaluation of the opportunity-cost-of-money theory of liquidity premia. I begin by examining the hypothesis that the liquidity premium should vary over time with the level of short-term interest rates. I then explore whether the introduction of central bank reserve remuneration changes the dynamics of liquidity premia. Most of the analyses below use T-bills as a near-money asset, but I also present some evidence with other highly liquid assets. Appendix A describes the data. All interest rates in the empirical analysis are monthly averages of daily annualized effective yields.

A Liquidity Premium of U.S. Treasury Bills

To measure the liquidity premium in U.S. T-Bills, I compare three-month T-bill yields to a maturity-matched general collateral (GC) repo rate. This repo rate is the interest rate for a 3-month term interbank loan. This loan is collateralized with a portfolio of U.S. Treasury securities ("general collateral"). Due to this backing with safe collateral, there is virtually no compensation for credit risk priced into the repo rate. An investment into a repo term loan is illiquid, because the investment is locked in during the term of the loan. In contrast, a T-bill investment is more liquid, because it can be re-sold easily. The spread between T-Bills and the repo rate reflects this liquidity differential.

The absence of a credit risk component in the GC repo rate makes the repo/T-bill spread a more accurate measure of the liquidity premium than alternative measures such as the commonly used Treasury/eurodollar (TED) spread. The TED spread compares T-Bill yields to unsecured interbank lending rates that contain a credit risk component. The repo/T-bill spread isolates the component of the TED spread that captures a liquidity premium.

Figure 1 shows monthly averages of the repo rate minus T-bill yields since the early 1990s. As the figure shows, the repo rate typically exceeds the T-Bill yield by a substantial amount between 10 and 50 basis points (bps = 1/100s of a percent) during the sample period covered in the figure. The focus of this paper is on understanding why this spread varies over time.

To apply the model to U.S. data, I assume that deposit rates on highly liquid demand deposits are essentially zero, and hence $\delta(0) \approx 0$ in equation (9), so that

$$i_t - i_t^b \approx \frac{\ell_b(\xi_t)}{\ell_d(\xi_t)} i_t \tag{10}$$

Thus, the liquidity premium, $i_t - i_t^b$, should, in the absence of shocks to the multipliers ℓ_b and ℓ_d, be proportional to the level of short-term interest rates. I measure the level of short-term interest rates with the level of the federal funds rate. One might prefer to use the 3-month GC repo rate instead, so that the same proxy is used for i_t on the left-hand and right-hand side of (10), but this would make virtually no difference. There is very little difference between monthly averages of these rates, and their correlation is close to one. The advantage of using the federal funds rate is that it is available for a longer time period than the GC repo rate. This allows me to use the same type of rate to measure the level of short-term interest rates in other analyses below that use longer data samples with alternatives to the GC repo rate in the calculation of the liquidity premium in T-bills.

Figure 1 shows that the time-variation in this spread is—outside of crisis periods—remarkably consistent with (10). As the plot demonstrates, the liquidity premium component of T-Bill yields comoves strongly positively with the level of the federal funds rate. At the medium-term frequencies illustrated by the plot in Figure 1, the opportunity-cost of money mechanism that leads to (10) seems to be the dominant influence on the liquidity premium, rather than the liquidity demand shocks that seem to have some impact at weekly frequencies according to the evidence in Sunderam (2013) or the very low-frequency changes in the supply of Treasuries emphasized by Krishnamurthy and Vissing-Jorgensen (2012b).

During periods of financial market turmoil, however, this roughly proportional relationship is clearly broken. During the LTCM crisis in September 1998, or during the height of the financial crisis in 2008, the repo/T-bill rate spread is unhinged from its usual relationship with the federal funds rate. Following (10), this can be explained if the liquidity service of deposits is impaired relative to T-Bills, for example, because bank customers have doubts about the safety and liquidity of deposits during a financial crisis period. This leads to a fall in the liquidity multiplier of deposits, $\ell_d(\xi_t)$, relative to $\ell_b(\xi_t)$, which raises $i_t - i_t^b$.

Table I, column (1), presents the results of regressions of the repo/T-bill spread on the federal funds rate. Since the main focus of this paper is on the behavior of liquidity premia in "normal" times outside of crisis periods, these regressions use data only up to June 2007 so that the financial crisis period is excluded. The results confirm the visual impression from Figure 1: The spread is strongly positively related to the federal funds rate. An increase in one percentage point of the federal funds rate is associated with a fall of the T-bill yield

Table I: Liquidity Premia and Fed Funds Rate: Short Sample

The sample period is May 1991 to June 2007. The data consists of monthly averages of daily rates. The dependent variable is a yield spread expressed in basis points; the explanatory variable (federal funds rate) is expressed in percent. Newey-West standard errors (12 lags) are shown in parentheses.

	Repo/T-Bill (1)	CD/T-Bill (2)	2y Off/OnRun (3)	T-Note/T-Bill (4)
Intercept	-8.66	2.13	-0.32	0.41
	(3.62)	(4.14)	(0.24)	(2.38)
Fed funds rate	5.36	6.69	0.37	1.09
	(0.99)	(1.21)	(0.07)	(0.79)
Adj. R^2	0.34	0.34	0.08	0.05
#Obs.	194	194	194	194

relative to the GC repo rate of 5.36 bps (s.e. 0.99).

Alternative near-money assets. While T-bills are the most liquid Treasury security in the US, other Treasury securities with longer maturities can also have some near-money properties. In particular, the most recently issued "on-the-run" Treasury notes and bonds are traded in a highly liquid market and there is empirical evidence that they trade at a liquidity premium compared with older "off-the-run" issues that are less liquid (see, e.g., Warga 1992; Krishnamurthy 2002).

Column (3) in Table I looks at the spread between two-year off-the-run and on-the-run notes. I focus on two-year notes because their shorter maturity makes them more similar to T-bills than other Treasury notes and bond with longer maturities. Moreover, two-year notes are issued on a regular monthly auction cycle that makes it easier to construct a consistent series of the off-the-run/on-the-run spread over a long time period than with longer-maturity notes and bonds that are on a less regular auction schedule.

To construct the spread, I compare the yield of the most recently issued on-the-run note with the yield of the nearest off-the-run note issued one auction earlier. The two notes are, however, not exactly the same in terms of maturity and coupon rate. Especially when the yield curve is steep at the short end, one would expect some difference in yields even without any liquidity premia. For this reason, I follow Goldreich, Hanke, and Nath (2005) and use an off-the-run zero-coupon bond yield curve to value the cash flows of the on-the-run note and the nearest off-the-run note. This allows me to construct a synthetic yield difference between the on-the-run and nearest off-the run note that reflects the shape of the off-the-run yield curve at each point in time. I adjust the off-the-run/on-the-run spread with this synthetic yield difference. This adjustment accounts for the differences in maturity and coupon rates between the two notes. The off-the-run zero-coupon yield curves used in this method are obtained from the Federal Reserve Board, and they are based on the method of Gürkaynak, Sack, and Wright (2007).

As column (3) in Table I shows, there is a statistically significant positive relationship between the level of the federal funds rate and the off-the-run/on-the-run spread. The magnitude of the liquidity premium, however, is much smaller in this case—on the order of a few basis points. Correspondingly, the magnitude of the coefficient on the federal funds rate is much smaller than in column (i). The point estimate implies that a one percentage point change in the fed funds rate translates into a change in 0.37bps (s.e. 0.07) in the off-the-run/on-the-run spread.

Column (4) looks at the spread between T-bills and less liquid off-the-run two-year Treasury notes. Amihud and Mendelson (1991) show that this spread reflects a liquidity premium. I construct this spread by looking for two-year Treasury notes with remaining maturity of around three months. Then I compare the yield of each Treasury note with the the average yield of two T-bills that straddle the maturity of the Treasury note. As Table I shows, the coefficient in a regression of this spread on the federal funds rate is positive, but it is not statistically significant in this sample.

Extended sample. Figure 2 presents a similar analysis with longer data series starting in 1976. I do not have repo rate data for time periods before the 1990s, and hence the liquidity premium in this figure is calculated by comparing T-bill yields with certificate of deposit (CD)

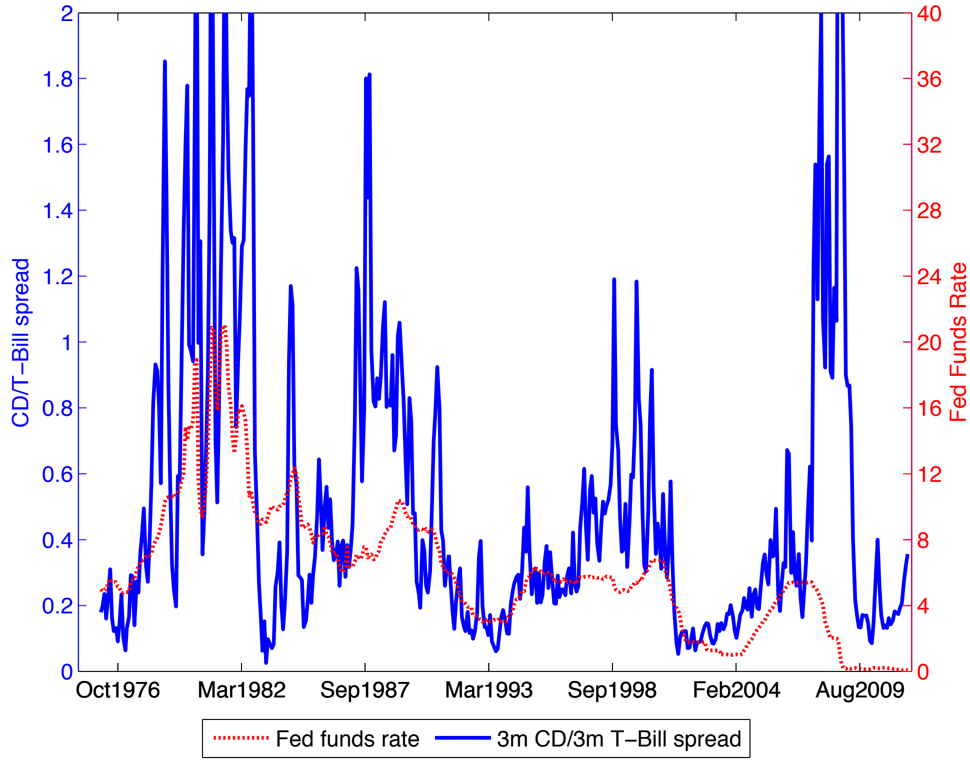

Figure 2: Spread between 3-month Treasury Bill yield and 3-month CD Rate

rates rather than with GC repo rates. The spread to CD rates is an imperfect measure of the liquidity premium, because a CD rates contain a credit risk component. However, outside of crisis periods, this credit risk component is small. In the periods since the early 1990s when both repo rate and CD rate data is available, there is typically only a small difference between CD rates and GC repo rates. Comparing the spread plotted in Figure 2 with the spread in Figure 1 one can see that the magnitude of the spread is quite similar in both cases. The big exception is the financial crisis period starting in 2007. Here the CD/T-bill spread uncoupled much more strongly from its usual relationship with the level of short-term interest rates than the repo/T-bill spread.

It is also apparent from Figure 2 that the CD/T-bill spread has a similarly strong positive relationship with the level of the federal funds rate as the repo/Tbill spread in Figure 1. This strong positive correlation is therefore not specific to the post-1990 period.

Table II: Liquidity Premia and Fed Funds Rate: Long Sample

The sample period is January 1976 to June 2007. The data consists of monthly averages of daily rates. The dependent variable is a yield spread expressed in basis points; the explanatory variable (federal funds rate) is expressed in percent. Newey-West standard errors (12 lags) are shown in parentheses.

	CD/T-Bill (1)	2y Off/OnRun (2)	T-Note/T-Bill (3)
Intercept	-6.31	0.52	2.89
	(4.53)	(0.72)	(2.17)
Fed funds rate	8.14	0.25	1.01
	(0.70)	(0.13)	(0.28)
Adj. R^2	0.51	0.03	0.06
#Obs.	378	378	378

The similarity of the CD/T-bill and the repo/T-bill spread can also be seen in column (2) of Table I. Regressing the CD/T-bill spread on the federal funds rate yields a coefficient estimate that is of similar magnitude as in the column (i) where the Repo/T-bill spread is the dependent variable.

Column (1) in Table II exploits the advantage of a longer sample for the CD/T-bill spread and shows the results of a similar regression over the time period from 1976 to 2007. The point estimate for the coefficient on the federal funds rate is quite similar to the estimate in column (ii) of Table I. This provides further confirmation that the strong relationship between the liquidity premium of T-bills and the level of short-term interest rates is not specific to the post-1990 period.

Columns (2) and (3) furthermore show that the off-the-run/on-the-run and the T-note/T-bill spread are positively related to the level of the federal funds rate in this longer sample, too. Moreover, the point estimate of the coefficient in the T-note/T-bill spread regression in column (3) is now more than three standard errors away from zero, indicating statistical significance at conventional levels.

Isolating the crisis component in liquidity premia. Figure 1 suggests that the

Table III: Decomposition of Liquidity Premia: Relation to VIX

The sample period is May 1991 to October 2011. The data consists of monthly averages of daily rates. The dependent variable is CBOE VIX index expressed in percentage points; the explanatory variables are yield spreads expressed in basis points. Newey-West standard errors (12 lags) are shown in parentheses.

	Repo/T-Bill (1)	CD/T-Bill (2)	2y Off/OnRun (3)	T-Note/T-Bill (4)
Intercept	21.23	21.61	23.59	23.30
	(1.75)	(2.21)	(2.63)	(2.52)
$\text{proj}(spread\|i_t)$	-0.16	-0.10	-3.24	-0.77
	(0.10)	(0.07)	(1.87)	(0.44)
$spread - \text{proj}(spread\|i_t)$	0.26	0.11	0.24	0.52
	(0.05)	(0.02)	(0.49)	(0.12)
Adj. R^2	0.29	0.39	0.09	0.33
#Obs.	246	246	246	246

liquidity premium consists of two components with very different cyclical properties. The first is the component related to the opportunity cost of money that I focus on for the most part in this paper. The second component is one that appears predominantly in times of financial market stress like the LTCM crisis in September 1998 or the financial crisis in 2007-09. To properly interpret the meaning of the magnitude of liquidity premia at a given point in time, or to use them as predictors of other variables—e.g., as forecasters of real activity as in Stock and Watson (1989), Bernanke (1990), Friedman and Kuttner (1992) and Bernanke and Blinder (1992)—it is important to take into account that these two components carry different information about the state of the economy.

Table III illustrates the different cyclical properties of the two components. The regressions reported in this table show how the two components relate to the Chicago Board Options Exchange VIX index of implied volatilities of S&P500 index options. The VIX index is a widely used indicator of financial market stress. Periods of financial market turmoil and market illiquidity tend to coincide with high levels of the VIX index (Adrian and Shin 2010; Bao, Pan, and Wang 2011; Brunnermeier, Nagel, and Pedersen 2008; Longstaff, Pan, Pedersen, and Singleton 2010; Nagel 2012).

The dependent variable in Table III is the VIX index expressed in percentage points. The explanatory variables are the yield spreads from Table I decomposed into their projection on the federal funds rate, i.e., the fitted value from Table I, denoted $\text{proj}(spread|i_t)$ and the residual, denoted $spread - \text{proj}(spread|i_t)$. While the regressions in Table I use only data excluding the financial crisis period after June 2007, the calculation of the fitted values for $\text{proj}(spread|i_t)$ applies the coefficients from Table I to the full sample period until October 2011.

As Table III shows, the two components correlate very differently with the VIX. The opportunity-cost-of-money component $\text{proj}(spread|i_t)$ has a negative coefficient, albeit with weak statistical significance. The federal funds rate is high during booms when the VIX index tends to be low. In contrast, the residual component $spread - \text{proj}(spread|i_t)$ has a strongly positive association with the VIX index. For example, focusing on column (1), if the repo/T-bill spread widens by 10bp without a corresponding change in the federal funds rate, this is associated with a 2.6 percentage point rise in the VIX index (for comparison, the average level of the VIX is close to 20 percent). For all yield spreads except the off-the-run/on-the-run spread in column (3), the coefficient on this residual component is at least four standard errors greater than zero.

These results are consistent with the view that the residual component $spread - \text{proj}(spread|i_t)$ carries information about stress levels in the financial system. Seen through the lens of the model, eq. (10), the liquidity multiplier of deposits, $\ell_d(\xi_t)$, falls in times of turmoil relative to the liquidity multiplier of T-bills, $\ell_b(\xi_t)$, which leads to an abnormally high level of the liquidity premium.

Taxes. One potential concern with these analyses is that differences in taxation could drive a wedge between yields of T-Bills and private-sector money market rates. Earlier research, e.g. Cook and Lawler (1983), has argued that differences in state tax treatments explain the CD/T-bill rate spread. However, it is not clear whether these state-tax treatments affect prices in world in which some big investors are tax-exempt and taxable global financial institutions undertake elaborate efforts to minimize their tax bill. Fortunately, there is a way to directly address this issue empirically. For a number of years, the Federal Home Loan Bank (FHLB) has issued short-term discount notes with maturities in similar ranges as T-bills.[4] These discount notes receive the same tax treatment as Treasury Bills and FHLB debt is also explicitly guaranteed by the Federal government (Cowan and Petrine 2002). Thus, a spread between FHLB discount note yields and T-bill yields cannot be driven by taxation differences nor by credit risk. As Figure 3 shows, the FHLB note/T-bill spread is quantitatively similar to the repo/T-bill spread. The correlation between the two series is 0.91. This suggests that a the repo/T-bill spread cannot be explained by differential tax treatment. Instead, both the FHLB note/T-bill spread and the repo/T-bill spread reflect the superior liquidity of T-bills.

In addition, the off-the-run/on-the-run and T-note/T-bill spreads in analyzed in Tables I and II also compare instruments with similar tax treatment. The existence of spread between their yields and its variation over time therefore cannot be explained by a tax story either.

IV The Effect of Reserve Remuneration Policies

As the evidence in the previous section shows, the assumption that $\delta(i_t^m) \approx 0$ in

$$i_t - i_t^b = \frac{\ell_b(\xi_t)}{\ell_d(\xi_t)}[i_t - \delta(i_t^m)] \tag{11}$$

provides a good description of the behavior of liquidity premia in the U.S. until the financial crisis. This was a period during which the Federal Reserve did not pay IOR, i.e., we had $i_t^m = 0$. However, in October 2008 the Federal Reserve started paying IOR. Due to the extremely low level of short-term interest rates since 2008, the IOR so far remained very close to zero, though, which means that there is unlikely to be much effect on liquidity premia. A number of other countries introduced IOR at earlier points during the past two

[4] I am grateful to Allan Mendelowitz for providing the discount note yield data

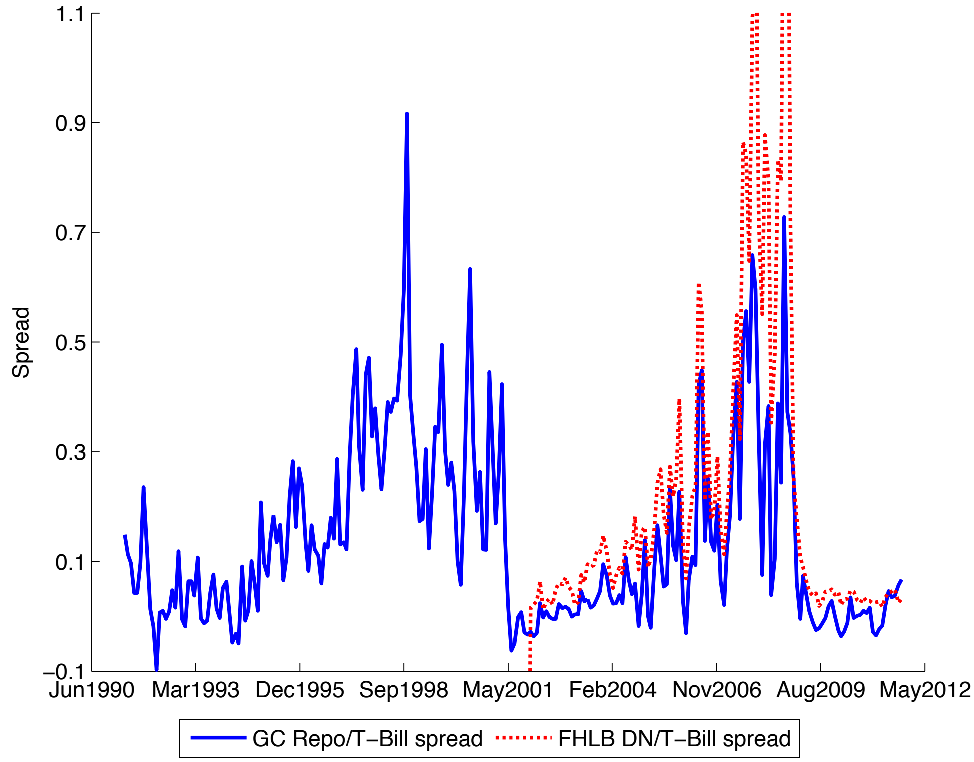

Figure 3: Spread between Repo/T-bill spread compared with T-bill/FHLB discount note spread

decades when short-term interest rates were higher. In those cases, detectable effects on liquidity premia could potentially exist.

Whether the assumption of $\delta(i_t^m) \approx 0$ in (11) still provides a good prediction of liquidity premia after the introduction of IOR is an open question. It is possible that the introduction of IOR lowers the marginal cost of maintaining precautionary liquidity sufficiently so that competition among banks drives demand deposit rates up to a level significantly above zero, perhaps close to i_t^m. On the other hand, it is also possible that the opportunity cost of reserve holdings is not a major factor in the determination of equilibrium deposit rates. In the former case, one would expect liquidity premia to shrink following the introduction of IOR and show little variation with the level of short term interest rates. In the latter case, they should still be predicted well by (11) with $\delta(i_t^m) \approx 0$.

To investigate this question empirically, I examine Canada (which introduced IOR in 1999) and the UK (which introduced IOR in 2001).

A Canada

Figure 4 shows the history of the liquidity premium, measured as the spread between prime commercial paper (CP) rates and Candadian T-bills at 3-month maturity. For Canada, I do not have a sufficiently long series for GC 3-month term repo rates, and so I use the prime CP rate as a proxy for the market rate for (illiquid) 3-month term loans. The overnight interest rate shown by the dotted line in Figure 4 is the CORRA overnight GC repo rate since December 1997, and prior to that date, the overnight Canada dollar LIBOR rate.

There are noteworthy facts in Figure 4. First, the liquidity premium of Canadian T-bills is positive on average. Second, it is positively correlated with the level of short-term interest rates, similar to the US data in Figure 2. For example, similar to the US, Canada experienced high levels of liquidity premia in the early 1980s when short-term interest rates were in the double digits. The co-movement of liquidity premia with the level of short-term interest rates is therefore not unique to the US.

The Bank of Canada introduced IOR in February 1999, with i_t^m set to 25bps below the target interbank lending rate (Bowman, Gagnon, and Leahy 2010), as shown by the vertical line in Figure 4. If deposit rates changed one-for-one with i_t^m, this would have a dramatic effect on the magnitude of liquidity premia according to (11): In 1999, short-term rates were at $i_t \approx 6\%$ and so with the introduction of IOR $i_t - i_t^m$ shrank from about 6% to 0.25%.

Figure 4, however, indicates that the introduction of IOR had little effect on the magnitude of the liquidity premium of Canadian T-bills. While the introduction of the IOR is preceded by some positive spikes in the liquidity premium in 1997 and 1998—presumably a consequence of the East Asian and LTCM crises occurring at the time—there is little evidence of a persistent change in the way the liquidity premium relates to the level of short-term interest rates. The time-series behavior of the liquidity premium is quite similar before and

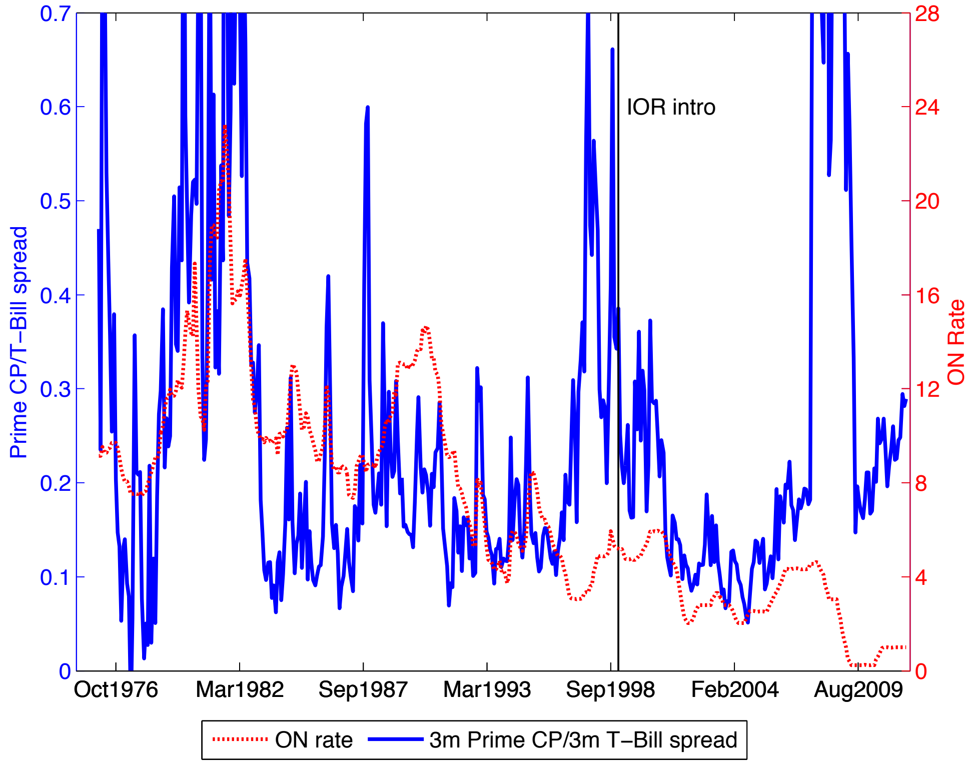

Figure 4: Commercial paper/T-Bill Spread in Canada

after the IOR introduction.

Table IV confirms the visual impression from Figure 4. The results in this table are based on data from January 1976 to June 2007, i.e., excluding the recent financial crisis period. The regression of the prime CP/T-bill spread in column (1) yields a positive coefficient on the overnight rate. The point estimate suggests that a one percentage point rise in the overnight rate is associated with a 2.15 bps (s.e. 0.59) rise in the liquidity premium. Column (ii) interacts the overnight rate with a dummy that equals one in the periods after the introduction of IOR. If the IOR introduction reduced liquidity premia, one would expect a negative coefficient on this interaction term. In contrast, the estimate in column (2) is positive, albeit not significantly different from zero at conventional significance levels.

One somewhat puzzling feature of the data is the elevated prime CP/T-bill spread in Figure 4 towards the very end of the sample. Possibly, this reflects a higher perceived riskiness

Table IV: Liquidity Premium and IOR: Canada

The sample period is January 1976 to June 2007. The data consists of monthly averages of daily rates. The dependent variable is a yield spread expressed in basis points; the explanatory variable (CORRA, a general collateral overnight rate since December 1997; overnight LIBOR in earlier periods) is expressed in percent. The IOR dummy is set to one in the time periods following the introduction of IOR in February 1999. Newey-West standard errors (12 lags) are shown in parentheses.

	Prime CP/T-Bill (1)	Prime CP/T-Bill (2)
Intercept	6.38	4.93
	(4.27)	(8.30)
ON rate	2.15	2.25
	(0.59)	(0.86)
IOR dummy		-5.40
		(8.51)
IOR dummy × ON rate		2.11
		(1.08)
Adj. R^2	0.26	0.26
#Obs.	378	378

of prime commercial paper following the financial crisis. If so, this would suggest that the prime CP/T-bill spread is not a good proxy for the liquidity premium during the last two years of the sample. Consistent with this explanation, the US CD rate/T-bill spread in Figure 2 shares this feature, but not the GC repo/T-bill spread (which is virtually free of credit risk) in Figure 1.

B United Kingdom

Figure 5 plots monthly averages of the CD rate/T-bill spread at 3-month maturity for the UK since 1978. The short-term interest rate shown in the figure is SONIA, an unsecured overnight interbank rate, from 1997, and the Bank of England's repo rate before 1997. As in Canada and the US, the liquidity premium of UK T-bills is positive on average and positively correlated with the level of short-term interest rates. As in the US and Canada, the CD rate/T-bill spread exhibits positive spikes unrelated to short-term interest rates during the

Table V: Liquidity Premium and IOR: UK

The sample period is January 1978 to June 2007. The data consists of monthly averages of daily rates. The dependent variable is a yield spread expressed in basis points; the explanatory variable (SONIA, an unsecured overnight interbank rate) is expressed in percent. Newey-West standard errors (12 lags) are shown in parentheses.

	CD/T-Bill (1)	CD/T-Bill (2)
Intercept	-16.89	-15.19
	(7.16)	(11.11)
ON Rate	6.01	5.87
	(1.00)	(1.29)
IOR dummy		6.91
		(12.05)
IOR dummy × ON rate		-2.11
		(1.71)
Adj. R^2	0.60	0.60
#Obs.	354	354

East Asian and LTCM crises in 1997 and 1998, as well as the financial crisis starting in 2007.

In June 2001, the Bank of England (BoE) introduced an overnight deposit facility. Excess reserves placed into the deposit facility earned an interest rate of 100bps below the BoE's main policy rate. Starting in March 2005, the spread to the main policy rate was changed a number of times to 25bps and 50bps (Bowman, Gagnon, and Leahy 2010). Figure 5 does not suggest that this change in reserve remuneration policy in 2001 had a substantial effect on the liquidity premium of UK T-Bills. Until the onset of the financial crisis in 2007, the CD rate/T-bill spread continued to be substantially positive, and it correlated positively with the level of short-term interest rates.

Among the three countries examined in this study, the UK shows the most pronounced rise in the CD rate/T-bill spread towards the end of 2011 in Figure 5. A plausible explanation for this rise is that it reflects a rise in the perception of bank credit risk in the wake of the European debt crisis that was building up around that time.

Table V presents regressions of the UK's CD rate/T-Bill spread on the level of the short-

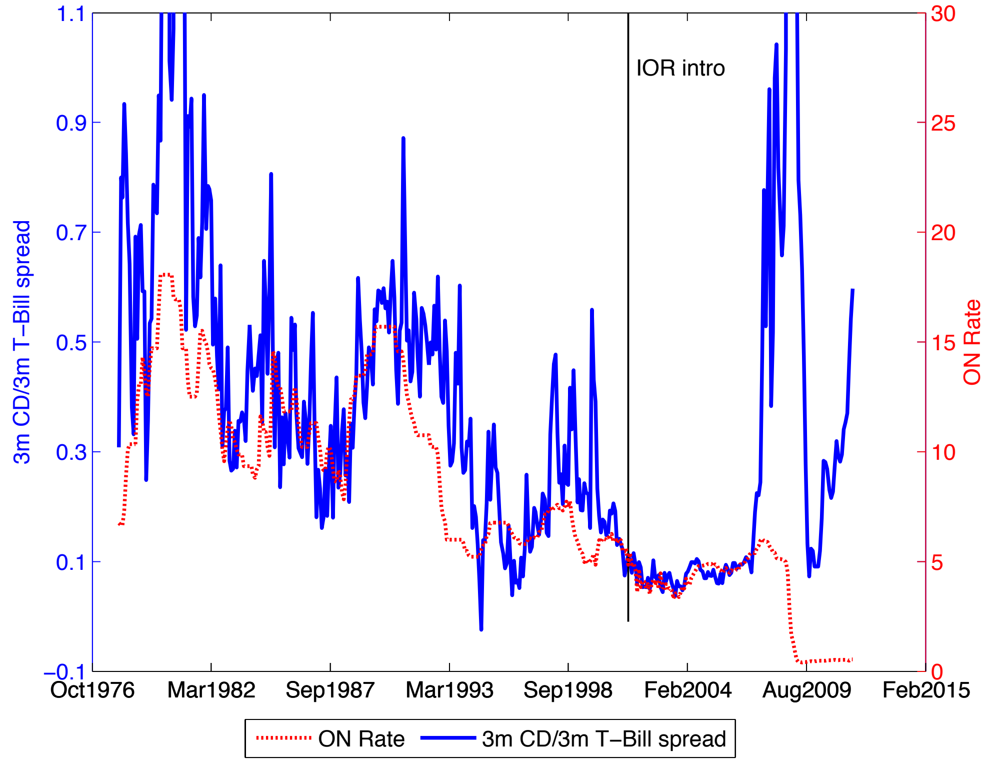

Figure 5: CD/T-Bill Spread in the UK

term interest rate using data up to June 2007. Column (1) shows that there is a strong positive relationship between the level of the overnight rate and the CD rate/T-Bill spread. The magnitude of the coefficient is quite similar to the estimate in US data in Table I: a one percentage point rise in the overnight rate is associated with a 6.01 bps (s.e. 1.00) rise in the liquidity premium. The interaction term with the IOR dummy in column (2) receives a negative coefficient. However, the combined effect with the ON rate variable evaluated at the point estimates ($5.87 - 2.11 = 3.76$) is still a strong positive effect of the ON rate. Moreover, at conventional significance levels, one cannot reject the hypothesis that the coefficient on the interaction is zero.

Thus, the combined evidence from the UK and Canada offers little support for the conjecture that the introduction of IOR could uncouple liquidity premia from their close relationship with the short-term interest rate. Even though IOR lowers the opportunity cost of holding one form of money (central bank reserves), this does not seem to carry over into a substantial reduction in the opportunity costs of holding other types of money (deposits) faced by non-banks.

Recent experience with IOR in the US also points at frictions that prevent market participants from arbitraging discrepancies between IOR and open-market rates. After the Federal Reserve introduced IOR in October 2008, the federal funds rate has persistently traded below IOR. As Bech and Klee (2011) argue, this reflects the fact that some large participants in the federal funds market are not eligible to receive IOR. Instead, they have to lend their funds in the federal funds market to banks who are eligible to receive IOR. These banks are not bidding for these funds aggressively enough to push the federal funds rate to the level of IOR. This illustrates that payment of IOR does not automatically establish the level of IOR as the floor for open-market and deposit rates.

V Conclusion

The evidence in this paper suggests that liquidity premia of near-money assets reflect the opportunity cost of holding money. When interest rates are high, the opportunity costs of holding money are high, and market participants are willing to pay a big premium for highly liquid money substitutes such as T-bills. As a consequence, liquidity premia are positively correlated with the level of short-term interest rates. This interest-rate related variation is a dominant driver of liquidity premia at business cylce frequencies, except in periods of financial market turmoil when liquidity premia are elevated relative to their normal level.

Payment of IOR could potentially reduce and stabilize liquidity premia because IOR reduces the opportunity cost of holding money for at least some market participants (banks with reserve accounts at the central bank). However, the evidence from Canada and the UK shows that liquidity premia remained strongly tied to the level of short-term interest rates after the introduction of IOR. Evidently, payment of IOR did not substantially affect the opportunity cost of holding money for non-bank market participants.

One might conjecture that liquidity premia would indeed shrink and uncouple from the short-term interest rate if a much broader group of market participants—perhaps even including households and non-financial corporations—had direct access to interest-bearing electronic central bank money.

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Appendix: Data Sources

This appendix describes the sources of the data used in this paper. All yields are expressed as effective annual yields.

A United States

Treasury bill and Treasury note yields. Data for T-bills and T-notes is from the daily CRSP database. Every day I choose the T-bill closest to 91-day maturity and calculate its yield from the midpoint of the bid and ask quotes provided in the CRSP database. To match T-notes with similar maturity T-bills, I look, each day, for the two-year note with remaining maturity closest to 91 days maturity and two T-bills whose maturity straddle the T-note's maturity. To construct the T-note/T-bill spread I subtract the linear interpolation of the two T-bill yields from the T-note yield as in Amihud and Mendelson (1991).

On-the-run and off-the-run Treasury notes. To construct the spread between two-year on-the-run and off-the-run notes, I compare the yield of the most recently issued on-the-run note with the yield of the nearest off-the-run note issued one auction earlier. I follow Goldreich, Hanke, and Nath (2005) and use an off-the-run zero-coupon bond yield curve to value the cash flows of the on-the-run note and the nearest off-the-run note. I adjust the off-the-run/on-the-run spread with this synthetic yield difference. This adjustment accounts for the differences in maturity and coupon rates between the two notes. The off-the-run zero-coupon yield curves used in this method are obtained from the Federal Reserve Board, and they are based on the method of Gürkaynak, Sack, and Wright (2007).

Interbank rates. Daily GC repo rates are from Bloomberg, available from May 1991. CD rates are obtained from the FRED database at the Federal Reserve Bank of St. Louis. The source of these data is the H.15 Release of the Federal Reserve Board. The reported CD rates refer to average of dealer bid rates for large-denomination ($1,000,000 or greater) certificates of deposit. These large denomination CDs are not insured by the FDIC. Daily data for the effective federal funds rate based on the H.15 release is also obtained from the FRED database.

B Canada

Data on three-month T-bill yields are from Global Financial Data. The data comprises daily secondary market yields from 1990 and auction yields prior to 1990. Yields on three-month prime commercial paper and Canada dollar overnight LIBOR are also from Global Financial Data. The data is weekly until 1990 and daily subsequently. When the CORRA general collateral overnight repo rate becomes available on Datastream from 12/8/1997 onwards, I use CORRA as the short-term interest rate instead of LIBOR.

C United Kingdom

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Data on UK T-bill yields is from Datastream. Before 1996, use secondary market T-bill yields (LDNTB3M). From 1996 onwards, this series is often stale. For this reason, I use average yields from the weekly three-month T-bill tenders (UKTBTND) from 1996 until 2011. Monthly averages of CD rates and of the SONIA overnight interbank rate are from the Bank of England.