A Data Description

1. **Alternative benchmark rates:** We obtain backward-calculated (for the April 2014 – May 2018) and actual (from May 2018 on) SOFR rates from the New York Fed website. Data for the SONIA and reformed SONIA rate come from the BoE. ESTR and pre-ESTR rates are obtained from the ECB website.

2. **Libor and Euribor rates:** We obtain 3-month term LIBOR and overnight LIBOR for USD and GBP LIBOR, as well as 3-month EURIBOR and EONIA (as a measure of overnight EURIBOR) rates from the Bloomberg system.

3. **Key policy rates:** For the U.S., we use the IOER rate, for the U.K., we use the “bank rate”, and for Europe, we use the bank deposit rates. All three rates are obtained from Bloomberg.

4. **Government debt outstanding:** We use auction data from TreasuryDirect.com, the U.K. debt management office, and the German finance ministry to construct the daily volume of U.S., U.K., and German Treasury debt outstanding, respectively.

5. **Transaction volumes:** We obtain SOFR volumes, split into tri-party, GCF, and bilateral transactions from the New York Fed website. SONIA volumes come from the BoE. ESTR volumes are obtained from the ECB website.

6. **Reserves:** For the U.S., we use the total balances with Federal reserve banks; For the U.K., we use excess reserves at BoE deposit accounts; For Europe, we use excess reserves defined as deposits at the deposit account net recourse to the marginal lending facility. All three quantities are obtained from the Bloomberg system.

7. **Primary dealer net repo:** To construct primary dealers’ net repo positions, we obtain the volume of overnight repo and reverse repo positions against Treasury collateral from the New York Fed website.

8. **Fed security holdings:** We obtain the total assets on Fed’s balance sheet and the quantity of
Treasury securities held by the Fed from FRED.

9. *Additional U.S. rates:* Additional GCF repo data come from the DTCC website and tri-party repo data from BNY Mellon. The Effr is obtained from FRED.

10. *Euro-dollar futures:* Euro-dollar futures are futures contracts that allow investors to take positions on the 3-month Libor rate at a future point in time. Prices and open interest for Euro-dollar futures are obtained from the Bloomberg system.

11. *Fed funds futures:* Fed funds futures are futures contracts that allow investors to take positions on the average Effr in a given month. Prices and open interest for Fed funds futures are obtained from the Bloomberg system.

12. *SOFR futures:* SOFR futures rates for 1-month futures (which resemble Fed funds futures) and 3-month futures (which resemble Euro-dollar futures) prices and open interest are obtained from the Bloomberg system.

**B Additional Details on the EFFR**

The Effr is the benchmark rate in more than $20 trillion overnight index swaps (OIS) and one aim of U.S. monetary policy is to keep the Effr within a target corridor. Figure IA.1 compares the Effr to SOFR. As we can see from the figure, the Effr is relatively stable and tends to spike downward on quarter-ends and month-ends (although these downward spikes have diminished in early 2018).

![Figure IA.1. Comparison of SOFR and EFFR. This figure compares the level of SOFR (blue line) the Effr. To remove the effect of changes in policy target rates, each line represents the spread between the respective rate and IOER. The grey vertical lines indicate quarter-ends.](image)

The main lenders in the Fed Funds market are Government Sponsored Entities (GSEs), which
face less stringent regulatory requirements compared to banks and can be thought of as non-bank lenders in our framework (transaction type T1). Figure IA.2 illustrates the volumes in the Fed funds market over time and confirms that GSEs became the predominant lender after the financial crisis. Note that, prior to the financial crisis, the Fed Funds market was an important venue for banks to trade excess reserves. However, the increasing amount of excess reserves in the banking sector (which was a consequence of unconventional monetary policy) prompted the Fed to start paying interest on excess reserves (IOER) in December 2008, thereby lowering banks’ incentives to lend their excess reserves to other banks. Figure IA.2 shows that the major borrowers in the Fed Funds market are foreign banking offices (FBOs), which unlike domestic banks, do not pay a balance-sheet fee to the Federal Deposit Insurance Corporation and are responsible for 45% of the borrowing.

Figure IA.2. Fed Funds volumes by counterparty. This figure shows quarterly fed funds volumes, split by counterparty. The dashed vertical lines correspond to the quarters when IOER was introduced (Q4 2008), the FDIC reform (Q2 2011), the introduction of the RRP facility (Q3 2013), the public disclosure of the leverage ratio (Q1 2015), and the implementation of the MMF reform (Q4 2016). The source of these data are the financial accounts of the U.S. Chartered bank borrowing and lending in the fed funds market became only available in January 2012 and we use the amount of interbank lending by chartered depository institutions as a proxy before that date. To keep the exposition clear, we drop credit unions, which only have fed funds different from zero in four quarters.

C  The Impact of Regulation

We now compare the impact of the introduction of leverage ratio reporting on different collateralized and uncollateralized overnight rates in the U.S., the U.K. and Europe. As for the U.S. before, we regress the spread between overnight rate and policy target rate on QEnd, YEnd, and MEnd \ QEnd, testing if the dummy variable became more significant after January 2013. Because SOFR, the reformed SONIA rate, and ESTR are not available before 2013, we use the GCF
repo rate, SONIA, EONIA as well as the EFFR and overnight repo rates backed with U.K. gilts or German Treasuries as collateral. Focusing first on the U.S., Panels (1) and (2) of Table IA.1 show that month-end downward spikes in the EFFR and quarter-end upward spikes in GCF repo rates started appearing after 2013. Given that GCF repo can be viewed as interbank transactions while the EFFR corresponds more to transactions of type T1, this finding supports Hypothesis 1.

Turning to the U.K., Panels (3) and (4) show that quarter-end and month-end spikes became more pronounced post-2013 and that the spikes are more pronounced for repo rates compared to the uncollateralized SONIA rate. Focusing next on the Euro area, Panels (5) and (6) show that EONIA exhibits significant upward spikes at quarter-ends but not at month-ends. By contrast, the repo rate based on German collateral shows significant downward spikes at quarter-ends in the post-2013 period, which were upward spikes in the 2010 – 2013 period. In line with the LR being reported based on quarter-end snapshots in Europe, month-end spikes are insignificant for both EONIA and repo. However, the large quarter-end spikes in EONIA did not become more significant after 2013. This is most likely due to the impact of the European debt crisis on unsecured overnight rates in Europe, which increased volatility in the rate.

D Additional Descriptive Statistics

This section contains three additional descriptive statistics. Figure IA.3 compares the 6-month SOFR average, computed in arrears, to the option-implied risk-free rate estimated by Van Binsbergen, Diamond, and Grotteria (2019).

Figure IA.4 shows the average open interest in Euro-dollar futures, averaged from one expiry date to the next, split into three maturity buckets: greater than 2 year, but less than 3 years; greater than 3 years but less than 4 years; and greater than 4 years. Figure IA.5 compares monthly gross notional of interest rate derivatives reported to DTCC split into contracts referencing LIBOR and contracts referencing SOFR.
Table IA.1 Changing reporting-date spikes in different overnight rates. This table shows the results of regressing the spread between the indicated overnight rate and key policy rate for the respective area on several dummy variables. QEnd and YEnd are dummy variables that equal one on the last trading day of a quarter or year and zero otherwise. MEnd \ QEnd is a dummy variable that equals one on the last day of a month if that day is not the last day of a quarter, and zero otherwise. \( I_{\geq 2013} \) is a dummy variable that equals one if the observation is after January 2013 and zero otherwise. All specifications include year-quarter fixed effects. The sample period is January 2010 to December 2019. The numbers in parantheses are Newey-West t-statistics. ***, **, and * indicate significance at a 1%, 5%, and 10% level respectively.

<table>
<thead>
<tr>
<th></th>
<th>EffR (1)</th>
<th>GCF (2)</th>
<th>SONIA (3)</th>
<th>Repo UK (4)</th>
<th>Eonia (5)</th>
<th>Repo DE (6)</th>
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<tr>
<td>QEnd</td>
<td>-4.79***</td>
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<td>3.42</td>
<td>-0.41</td>
<td>23.59***</td>
<td>10.75***</td>
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<td></td>
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<td>(0.39)</td>
<td>(1.32)</td>
<td>(-0.32)</td>
<td>(3.14)</td>
<td>(3.05)</td>
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<td>YEnd</td>
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<td>-5.89*</td>
<td>-10.15</td>
<td>-24.62**</td>
<td>-29.31***</td>
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<tr>
<td></td>
<td>(0.66)</td>
<td>(-1.12)</td>
<td>(-1.80)</td>
<td>(-1.52)</td>
<td>(-2.24)</td>
<td>(-3.92)</td>
</tr>
<tr>
<td>MEnd \ QEnd</td>
<td>0.36</td>
<td>3.93***</td>
<td>0.38</td>
<td>-1.59***</td>
<td>3.41</td>
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<tr>
<td></td>
<td>(1.37)</td>
<td>(4.29)</td>
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<td>QEnd \ I_{\geq 2013}</td>
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<td>-15.66*</td>
<td>-23.85***</td>
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<td></td>
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<td>(3.91)</td>
<td>(-2.54)</td>
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<td>3.27</td>
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<td>25.94**</td>
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</tr>
<tr>
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<td>2,518</td>
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</table>

Figure IA.3. Comparison between term SOFR and other risk-free rate proxies. This figure compares 6-month term SOFR (computed in arrears) to 6-month constant maturity Treasury yields and the option-implied risk-free rate estimated in Van Binsbergen et al (2019), as well as an estimate of the option-implied rate using end-of-day option prices.
Figure IA.4. Open interest in Euro-dollar futures. This figure shows quarterly average open interest in euro-dollar futures, sampled between IMM dates. The Euro-dollar futures reference either USD Libor, GBP Libor, or EURIBOR. Volumes are split into three different maturity buckets: Maturity between 2 and 3 years ([2y, 3y]), maturity between 3 and 4 years ([3y, 4y]), and maturity greater than 4 years.
Figure IA.5. Interest rate swap volumes. This figure shows monthly gross trading volumes of interest rate swaps with Libor as underlying (blue line) and SOFR as underlying (black line). The transactions are obtained from the DTCC trade repository.

E Proof of Proposition 1

To prove Proposition 1, we proceed in three steps. First, we determine the agents’ optimal investments as functions of the rates $r$ and $\rho$. Second, we use these optimal investments to derive expressions for $r$ and $\rho$, conditional on agent $B$ either being constrained or unconstrained. Finally, we determine the region in which agent $B$ is constrained.

First, we start by determining $A$’s optimal investment in the risky asset, which is the solution to a standard mean-variance optimization problem and given as:

$$a = \frac{\mu - r}{\gamma \sigma^2},$$  

(1)

assuming a sufficiently large $W^A$. The remaining amount $W^A - a$ needs to be invested in risk-free assets. Subtracting the amount of outstanding Treasuries $\&$ gives the total amount that $A$ is lending to $B$:

$$W^A - a - \&.$$

(2)
The bank’s optimization problem is given as:

\[
\max_{b, \bar{b}} \left[ b(\mu - r - \gamma \beta \sigma^2) + \bar{b}(\rho - r) \right]
\]

\[\text{s.t. } b + \bar{b} \leq \frac{1}{x} W^B,\]

where we assume that both \(b\) and \(\bar{b}\) are positive (i.e. long positions in the risky asset and lending money to other banks). \(B\)’s Lagrangian is given as:

\[\mathcal{L}(b, \bar{b}, \lambda) = b \left( \mu - r - \gamma b \sigma^2 \right) + \bar{b}(\rho - r) - \lambda \left( x b + x \bar{b} - W^B \right)\]

and taking the first-order condition (FOC) gives:

\[
\frac{\partial \mathcal{L}}{\partial b} : \mu - r - \gamma b \sigma^2 - \lambda = 0 \iff b = \frac{\mu - r}{\gamma \sigma^2} - \frac{\lambda}{\gamma \sigma^2}
\]

\[
\frac{\partial \mathcal{L}}{\partial \bar{b}} : \rho - r - \lambda = 0 \iff \lambda = \rho - r
\]

If \(B\) is unconstrained, we have \(\lambda = 0\) and hence \(\rho = r\) and \(b = a\). If \(B\) is constrained, plugging \(\lambda\) in gives the following investment in the risky asset:

\[b = \frac{\mu - \rho}{\gamma \sigma^2}.
\]

In addition, if \(B\) is constrained, we know that \(b + \bar{b} = \frac{1}{x} W^B\) and hence

\[\bar{b} = \frac{1}{x} W^B - b.
\]

Second, to determine \(r\), we assume market clearing in the non-bank to bank lending market, which implies:

\[(W^B - b - \bar{b}) + (W^A - a - S) \leq 0. \quad (3)\]
Depending on whether $B$ is unconstrained or constrained, solving Equation (3) for $r$ gives:

$$r = \begin{cases} 
\mu - \frac{\gamma \sigma^2}{2} [(W^A - \bar{b}) + W^B - \bar{b}], & \text{if } B \text{ is unconstrained} \\
2 \left[ \mu - \frac{\gamma \sigma^2}{2} (W^A - \bar{b}) + W^B - \bar{b} \right] - \rho, & \text{if } B \text{ is constrained.}
\end{cases}$$

(4)

To determine $\rho$, we assume market clearing for bank lending:

$$\left( \frac{1}{x} W^B - b \right) + \bar{c} + \bar{c} = 0.$$  

(5)

Because we already know that $B$ being unconstrained implies that $\rho = r$, we focus on the case where $B$ is constrained and solving Equation (5) for $\rho$ leads to:

$$\rho = \mu - \gamma \sigma^2 \left( \frac{1}{x} W^B + \bar{c} \right).$$

(6)

Plugging $\rho$ into the constrained case in Equation (4) gives:

$$r = \mu - \gamma \sigma^2 \left[ (W^A - \bar{b}) - \left( \frac{1}{x} - 1 \right) W^B \right], \text{ if } B \text{ is constrained.}$$

(7)

Third, $B$ is unconstrained if $\frac{\mu - r}{\gamma \sigma^2} + \bar{b} < \frac{1}{x} W^B$, which is the case if:

$$\frac{\frac{1}{x} W^B}{W^A + W^B - \bar{b} + \bar{b}} < 1/2.$$  

Replacing $\bar{c}$ with $\bar{b}$ and rewriting the expressions in terms of $B$ completes the proof. ■

References