Hiding in plain sight: preferred habitat effects in short-term rates*

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Abstract

We investigate the causes of the failure of the expectations hypothesis (EH) in an ideal yet critical setting: repurchase (repo) agreements, the ultra-short term funding market underlying interbank lending. We identify a preferred habitat of agents who use special repo to fund their positions in fixed income markets by leveraging a regulatory reform which shortened the settlement time of *bond* markets. Trading patterns adjust accordingly in repo, allowing us to observe the habitat move from one maturity to another. A triple-differences identification strategy demonstrates that this shock deteriorated the EH performance of the affected segment, implying that preferred habitat effects can distort pricing even in pristine conditions. Finally, our results highlight a concerning usage of repo to fund leveraged positions, likely spurred on by the convenience yield provided by agents' safe asset collaterals.

Keywords: Expectations hypothesis, preferred habitats, repo markets, term structure of interest rates.

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The expectations hypothesis (EH) posits that long-term interest rates are determined by the market's current expectations of future short-term interest rates. The EH is one of the oldest and most fundamental theories of financial economics, having originated in the writings of Fisher (1896) and Keynes (1930), and is a precursor of rational expectations theory. However, the EH has routinely been rejected empirically across various asset classes and time periods.

We aim to understand the causes of this failure by analyzing the EH in repurchase agreement (repo) markets. Repo rates represent the cost of holding riskless securities and are the main funding rates for investors' bond positions along the yield curve. From a theory perspective, they represents an ideal testing ground: inter alia, repo rates are the ultra-short segment of the term structure; if the EH were to hold anywhere, one would expect it to be in such short-term tenors. But repo markets are critical in their own right: they are the lynchpin of interbank lending markets, and crucially serve as the transmission mechanism of monetary policy. In studying the causes of its failure in this segment, we use the EH as a diagnostic tool to uncover potential frictions in a critical juncture.

We first demonstrate that the EH actually holds when considering general collateral, but breaks down in the "special" segment. That is, those repos which specify a specific underlying bond as collateral clearly fail the EH test, even when we consider repos with the *same* underlying collateral. On the other hand, we cannot reject the EH in repo segments which do not impose conditions on the collateral choice (i.e., generals). We show a monotonic decrease in EH performance across segments as specialness increases. This dichotomy allows us to isolate the root cause of the EH rejection: what is it about the special segment which causes it to fail?

The main contribution of this paper is to explain these dynamics by identifying a preferred habitat effect. Our quasi-experimental set-up leverages a regulatory reform in which the European transaction settlement standards of *bond* markets were shortened to T+2 in 2014 (as opposed to the usual T+3 timeline). We observe that trading volumes in special repos adapted accordingly: a large shift in trading activity occurred from the spot-next to the tomorrow-next segment. Such a shift only occurred for specials; generals - which cannot be used to target a specific bond - were unaffected. We show the habitat is populated by agents who use repo to cover cash and security positions. For example, if an institution purchases a bond, it has a cash outlay due in T+3 days. In order to meet its commitment, it can repo the incoming bond to meet its cash obligation. When the fixed income settlement cycle shortened, these agents had to accordingly migrate to the corresponding maturity.

We then test whether this shift in habitat resulted in a pricing effect. We implement a difference-in-difference-in-differences model leveraging the fact that (i) only special repos were affected by the settlement change (and generals were not), and (ii) the tomorrow-next segment was affected, and the spot-next was not. We calculate the EH errors implied by these tenors when predicting the overnight rate. The results of our novel testing model suggests that the EH performed worse in the treated segment after this change: the EH error, as a percentage of the underlying rate, increased by 4% across all collaterals, an effect size of around 5-7 basis points. That is, the tomorrow-next tenor received an influx of trades which bid the repo rate up relative to the target overnight rate, as well as to untreated repos. This is powerful evidence of a preferred habitat dynamic.

Particularly impressive is the fact that this effect takes place in ultra-short term maturities, where the only difference in economic substance is a one-day difference in the settlement time. The extant literature has considered preferred habitat effects driven by shocks to pension fund demand or unconventional monetary policy, as in Greenwood and Vayanos (2010, 2014), but these were major shocks impacting long-term maturities spanning to 15 to 30 years. The fact that preferred habitat effects can distort pricing in such pristine conditions suggests that these markets are far less efficient than previously thought. Traditional explanations based on arbitrageurs' risk aversion are inapplicable in this setting, where duration risk plays little to no role. Instead, safe asset scarcity likely drives the inability to arbitrage spreads away.

The results of our experiment further indicate that leveragers dominated short-sellers in the shifted habitat. If an agent repos a bond in order to cover a cash outlay, this represents leveraging in economic terms; the inverse operation is a short-sale. Given a positive price impact, leveragers' repo trades bid up the rate, whereas short-selling bids it down. We run additional specifications additionally using order flow as a dependent variable; the results confirm our intuition. We rationalize this through the presence of specialness convenience yields which decrease the cost of cash borrowing in repo, thus incentivizing leveraging. Agents use the valuable, safe asset collateral on their books to obtain cheap funding with which they can pay for bond purchases. They can even use the borrowed to cash purchase further bonds, allowing for further repo cash borrowing, and so forth. Such a strategy allows for infinite leverage in theory and has previously caused financial turmoil in practice, and as such constitutes a source of financial risk.

Our results are significant for three reasons. First, we use the idealized setting of general collateral repos to show that the EH can indeed hold in perfect conditions, and is not just a theoretical construct. Interestingly, however, it fails in the special segment, even when we consider the same underlying collateral in our tests. In doing so, we contribute to the literature testing the EH in short-term rates (Longstaff (2000), Buraschi and Menini (2001), Della Corte, Sarno, and Thornton (2008)). While these papers have reached varying conclusions as to the EH performance, we point out that the fundamental aspect to consider is the conditions imposed on the choice of collateral.

Second, we explain the failure in special repo through a preferred habitat mechanism, as opposed to the usual time-varying risk premia, thus contributing to the literature on preferred habitat (Greenwood and Vayanos (2010, 2014), Vayanos and Vila (2021), Gourinchas, Ray, and Vayanos (2022), Greenwood, Hanson, Stein, and Sunderam (2023), Klingler and Sundaresan (2023), Jappelli, Pelizzon, and Subrahmanyam (2023)). Our novelty is that we identify such an effect in securities with identical maturities differing by a single day in settlement time, as opposed to the longer maturities studied in the literature. This implies that markets are less efficient and more segmented than perhaps previously understood. Limits to arbitrage driven by safe asset scarcity induce the preferred habitat in our setting.

Finally, we show a high degree of leverage in the repo market, which is spurred on by safe asset scarcity and convenience yields. The mechanism we describe implies that market participants continually use repo as a way to cover for upcoming cash/security deliveries. The safe asset status of their outstanding collateral allows them to do so at advantageous rates - indeed, they are paid to borrow cash. We thus contribute to the literature on convenience yields and repo specialness (Duffie (1996), Krishnamurthy and Vissing-Jorgensen (2012), Corradin and Maddaloni (2020), Arrata, Nguyen, Rahmouni-Rousseau, and Vari (2020)). Finally, our findings concerning this practice contribute to our understanding of the microstructure of repo markets (Mancini, Ranaldo, and Wrampelmeyer, 2016) and highlight a potential vulnerability for policy-makers to consider.

2 A brief literature review

Despite its standing as one of the most fundamental theories in finance, the empirical studies rejecting the EH are too numerous to list.[1] An exception is provided by Fama and Bliss (1987), who confirm earlier findings that forward rate forecasts of short-term interest rate changes fare poorly, but show that the 1-year forward rate has forecasting power for expected returns of 4- to 5-year U.S. Treasury bonds, which they attribute to the mean-reverting tendency of the 1-year rate. Campbell and Shiller (1991) find that for any combination of maturities between 1 month and 10 years in the U.S. term structure, high yield spreads forecast a rise in short-term interest rates and a declining yield of said bond, which is inconsistent with the EH. The EH has also been studied in foreign exchange (FX) markets by testing whether interest rate differentials between two currencies provide an unbiased conditional expectation of the future exchange rate. This is in essence a test of uncovered interest parity (UIP), and given the popularity of carry trades exploiting UIP's

[1] Reviews of this literature can be found in the references of Fama and Bliss (1987), Longstaff (2000), as well as Della Corte, Sarno, and Thornton (2008).

failure, it is unsurprising to hear that this iteration of the EH is strongly rejected.[2]

The econometric methodologies used to test for the EH have also advanced. Tests used to investigate the EH suffered from poor finite sample properties, size distortions, and power problems. The foremost issue, as identified by Campbell and Shiller (1991), is the overlapping-errors problem. Consider testing the EH by using a long-term rate with n periods to forecast a short-term rate of m periods. In such a case, one only has an entirely independent observation of the forecast power every n periods. If one is testing an n of say 1 year, but only has 10 years of data, then the problem becomes particularly acute. The best-in-class methodology is now the vector autoregression (VAR) framework developed by Bekaert and Hodrick (2001). The VAR makes for a powerful test of overlapping equations by applying orthogonality conditions based on the assumption of rational expectations.

The first study of the EH in repos was provided by Longstaff (2000), who found that overnight, weekly, and monthly repo rates are unbiased estimates of the average overnight rate for the period from 1991 to 1999. The repos under study were general collateral repos backed by U.S. Treasuries. The motivation for testing the EH at the extreme short end of the term structure is that if it fails there, it is unlikely to do better for longer-term maturities. Further, as repo rates represent the cost of capital for holding riskless securities, they are arguably better measures of the short-term riskless term structure than Treasury bill rates. Finally, repos are traded in an interbank market on anonymous, transparent, and liquid platforms cleared by central counterparties (Mancini, Ranaldo, and Wrampelmeyer, 2016), which allows for the stark reduction of counterparty credit risk. Longstaff (2000) cannot reject the EH and further finds no evidence for the existence of term premia, even up to weekly and monthly maturities. This finding is challenged and somewhat contradicted by Della Corte, Sarno, and Thornton (2008), who use the same dataset, albeit updated to include 1991 to 2005. They reject the EH statistically, and attribute their discrepancy to the lengthier data sample and their usage of more recent and powerful

[2] See Bekaert and Hodrick (2001) for a list of references.

VAR methods. However, they argue that the EH is economically insignificant by setting up a trading strategy in a mean-variance framework and demonstrating that it would yield no gains versus an allocation based on simple EH predictions.

Ranaldo and Rupprecht (2019) revisit this discussion and study the temporal and cross-sectional variation in the forward premium of repo rates. Their analysis is based on overnight and tomorrow-next rates in European repo markets, contrasting with previous work. They argue that the EH cannot be rejected when funding liquidity is low. Therefore funding risk premiums, collateral specialness, and the demand for funding immediacy are linked to whether the EH holds. Specialness in repos refers to the premium paid by a lender in order to obtain a specific collateral. Duffie (1996) shows that a bond traded with a specialness premium in the repo markets should be trading at a price premium in the cash market. This is confirmed empirically by Jordan and Jordan (1997), who find evidence that the overnight specialness premium in repo markets is reflected in cash markets.

This specialness is a manifestation of a "convenience yield," which can be defined as a non-pecuniary return in the form of liquidity and/or by virtue of being a safe asset (Gorton, 2017). The presence of such convenience yields has been empirically demonstrated by Krishnamurthy and Vissing-Jorgensen (2012) for U.S. Treasuries, in particular by showing that their supply (i.e. availability) is positively related to their yield. Nagel (2016) finds that the liquidity premia of near-money assets such as Treasury bills reflect the opportunity cost of holding money, which is largely determined by the interest rate level. Jiang, Lustig, Van Nieuwerburgh, and Xiaolan (2021) highlight the importance of bond convenience yields in the Eurozone by showing that they explain a larger fraction of bond yields than default spreads, thus having large ramifications for the management of sovereign debt.

Specialness in repo agreements has been analysed by Buraschi and Menini (2001), who study whether the term structure of long-term special repo spreads embeds a liquidity risk premium and the extent to which such term structures discount the future specialness of collaterals. They find that long-term repo spreads poorly forecast future convenience yields. They also strongly reject the EH in repo rates, both statistically and economically, and argue for the presence of a time-varying risk premium due to the conditional volatility of the special repo spread. Arrata et. al (2020) show how central bank bond purchases under the auspices of unconventional monetary policy cause asset scarcity, exerting downward pressure on repo rates. Ballensiefen and Ranaldo (2022) provide the first asset pricing analysis of repos, and show that a carry factor accounting for the heterogeneity in convenience yields and changes in safety / liquidity premiums is necessary for pricing these assets.

This paper will focus heavily on the link between the repo market and the bond market itself, a topic which has been studied by Ballensiefen (2023), who shows why on-the-run bonds are more likely to be delivered than cheapest-to-post securities. Our paper will argue that the link between bond and repo markets results in there being a preferred habitat (see Modigliani and Sutch (1966); Vayanos and Vila (2021)) for traders who exploit the connection between these two markets to either leverage or short-sell their bond trades. Greenwood and Vayanos (2010) use the 2004 UK pension fund reform as a demand shock for bonds with maturities of over 15 years. Greenwood and Vayanos (2014) studies a supply shock in the form of quantitative easing purchase programs on the yield curve. Klingler and Sundaresan (2023) demonstrate that the decline in swap rates below US Treasuries rates during the 2008-2015 period can be attributed to the demand from US pension funds for long-dated interest-rate swaps. Jappelli, Pelizzon, and Subrahmanyam (2023) provide a general equilibrium model where arbitrageurs seek to short-sell bonds trading on special and thus apply downward pressure on special repo rates.

3 Background and data

A repo contract is a short-term funding arrangement backed by collateral, usually a government debt security. The cash lender purchases the bond from the cash borrower, who pledges to repurchase it at maturity. The lender of the cash (borrower of the bond) is performing a reverse repo. The repo rate is an interest calculated based on the cash amounts being exchanged at the near and far legs of the transaction. Appendix A goes into further detail as to the mechanics of a repo transaction.

We focus on the European repo market, which is an ideal subject for study due to several appealing features. First, being a centrally cleared market mitigates various concerns commonly encountered in over-the-counter (OTC) markets such as counterparty risk, bargaining power, and unobservable bilateral banking relationships. Second, the ultra-short term tenors which constitute the repo market are the main funding rate for investors' bond positions along the entire yield curve. Furthermore, the overnight rate in particular is the rate through which monetary policy is implemented. Finally, our data allows for a granular breakdown among several critical dimensions which we will leverage in our analysis.

The dataset is created by combining the transactions contained in three major European electronic trading platforms: BrokerTec, Eurex Repo, and MTS Repo, and accounts for more than 70% of the European repo market.[3] Our data sample extends from January 2$^{\text{nd}}$, 2006, to June 30$^{\text{th}}$, 2020. The data can be broadly split into two segments, which is critical to our analysis. As mentioned, special repos are those trades where a specific collateral has to be delivered as part of the repo transaction. A specific bond ISIN ("International Securities Identification Number") has to be agreed upfront in the terms of the transaction as the collateral. Our dataset specifies which ISIN served as the collateral in each of our repo transactions. We can thus also divide these repos into the country of origin of the underlying collateral. In contrast, general repos do not require the borrower to provide a specific bond as collateral but rather makes reference to a basket of eligible bonds. As the lender cannot know which bond he will receive, these repos do not trade on special. Thus, the general (GC) repo segment is usually funding/cash-driven, whereas the special (SC) segment is principally concerned with sourcing collateral. The literature has observed that repo markets have become far more collateral-driven over the last decade, see Brand, Ferrante, and Hubert (2019) and Schaffner, Ranaldo, and Tsatsaronis (2019).

[3] For more details, please see Mancini et. al (2016) and Ranaldo and Rupprecht (2019).

The baskets which a GC repo refers to can vary in the characteristics of the eligible bonds. In particular, the baskets will refer to the country of the issuer (for example, a basket can only allow certain German Treasuries). This entails that the basket is not completely special; of course a basket allowing only German Treasuries contains an element of specialness w.r.t. the underlying collateral. The difference between a GC and an SC repo is that the lender cannot know which collateral he is going to receive. However, all of these repos can be said to be special to a certain extent given that the underlying baskets impose conditions on collateral eligibility.

We thus further differentiate a further kind of repo, which is those which are backed by collateral from the GC Pooling ECB (GCP) and GC Pooling EXTended (GCX) baskets. The former contains 3'000 securities eligible for open market operations at the ECB with minimum AA- credit ratings; the latter expands that to 14'000 securities with at least BBB- ratings (also eligible at the ECB). These baskets are interesting in that they have the broadest eligibility requirements in our data (the GCX even more so than the GCP). We thus define our measure of repo specialness as the difference between the repo rate in question and the rate of the GCP[4] repo with same maturity and trade date.

We filter our data to ensure consistency. We remove all repos which were prearranged (as they may have a different economic substance). Only repos in euro currency are considered, and repos with floating rates are dropped (due to difficulties in calculating the correct rate). Furthermore, we only consider overnight repos which settle before 11 a.m. as tom-next and spot-next repos settle at that time. We only consider repos (whether GC or SC) whose collaterals originate from the following six countries: Germany, France, Italy, Spain, Belgium, and the Netherlands. Additionally, we consider the GCP and GCX baskets which are not affiliated with any particular country. Appendix B provides summary statistics on our data.

[4] We principally use the GCP basket as it has fewer missing values in the time series. The GCX basket provides a useful robustness check.

4 The expectations hypothesis in repo markets

Consider again the example of forecasting a short-term m-period rate with a longer-term n-period rate. The EH states that the current n-period rate is a conditional expectation of the current and expected future m-period rates $n - m$ periods into the future. In a setting with continuously compounded interest rates R, we have :

$$R_t^n = \frac{m}{n} \sum_{i=0}^{(n-m)/m} E_t \left[R_{t+m \cdot i}^m \right] + C, \qquad \frac{n}{m} \in \mathbb{Z} \tag{1}$$

The constant C reflects a term premium which must stay constant throughout time t, but may vary for different maturities n and m. However, in the strong form of the EH, C must also equal zero.

Our set-up will consider three maturities: overnight (ON), tomorrow-next (TN), and spot-next (SN). An overnight repo, as the name suggests, is agreed on date t, cash and bond exchange hands that night, and the transaction is reversed the next day, $t + 1$. A tomorrow-next repo agreed today actually sees the exchange of collateral and cash at 11 a.m. "tomorrow", and is closed out on $t + 2$. Finally, a spot-next trade is similarly a one-day maturity, but settlement of the two legs occurs at $t + 2$ and $t + 3$ respectively. As all are one-period rates, there are three restrictions we can potentially test: (i) the TN rate should be an unbiased predictor of the next-day ON rate, (ii) the SN rate should similarly predict the ON rate of two days later, and (iii) today's SN rate should predict tomorrow's TN rate. These three maturities account for 94.5% of the data in our sample; repo markets are highly short-term in nature. Appendix C clarifies the structure of these repo tenors as well as the classical term structures used in equation (1) above.

The EH is a test of whether the forward premium s_t (or term spread, in case of bonds) is an unbiased predictor of expected future simple interest rates r_{t+1}. Consider the case of $m = 1$ and $n = 2$ in eq. (1), which gives us:

$$R_t^2 = \frac{1}{2} \left(R_t^1 + E_t \left[R_{t+1}^1 \right] \right) + C \tag{2}$$

There are no two-period repos in our data, but we can form one by combining e.g. an ON and a TN repo, given that $R_t^2 = \frac{1}{2}(r_t^{TN} + r_t^{ON})$. Converting to repo rates ($R_t^1 = r_t^{ON}$), we obtain:

$$r_t^{TN} = E_t\left[r_{t+1}^{ON}\right] + c, \qquad c = 2 \cdot C \tag{3}$$

which we can test in a regression framework as follows:

$$\Delta r_{t+1} = \alpha + \beta_1 \cdot s_t + u_{t+1} \tag{4}$$

In this setting, $\Delta r_{t+1} = r_{t+1}^{ON} - r_t^{ON}$ and $s_t = r_t^{TN} - r_t^{ON}$. Testing the EH in differenced form is desirable as most common statistical tests find a high degree of persistence in interest rates, and differencing reduces the possibility of spurious results (Anderson et. al, 1997).[5] If the EH holds, then $\beta_1 = 1$, and $-\alpha$ represents the term premium c (in the pure form of the EH, it is zero). It is trivial to derive similar conditions for the aforementioned cases (ii) and (iii), although we then observe different term premia. Many of the empirical problems concerning the EH stem from the fact that we observe multiple combinations of maturities of length n forecasting multiple iterations of the same rate m. This leads then to the methodological issues concerning overlapping-errors and so forth. We avoid such issues by eschewing simultaneous joint estimation of multiple predictor maturities. Given that, I will use plain regression analyses in the style of (4) to present some heuristics about the EH's behaviour in repo markets.

Let us now compare the performance of the EH across the various segments we have defined. Table (1) presents the results of running a regression model as defined in equation (4) on the various repo rates in our data. We run the regression for four different segments (1) the GCX basket, (2) the GCP basket, (3) all GC repos, and (4) all SC repos. Note that four segments are listed in decreasing order of "specialness." That is, GCX repos allow for the widest array of acceptable collateral, the GCP a bit less, GC repos allow for a basket of collateral, and SC repos require a specific bond (ISIN) as collateral.

[5] The EH in differences states that the term spread between long-term and short-term interest rates provides the conditional expectation of future changes in the short-term rate.

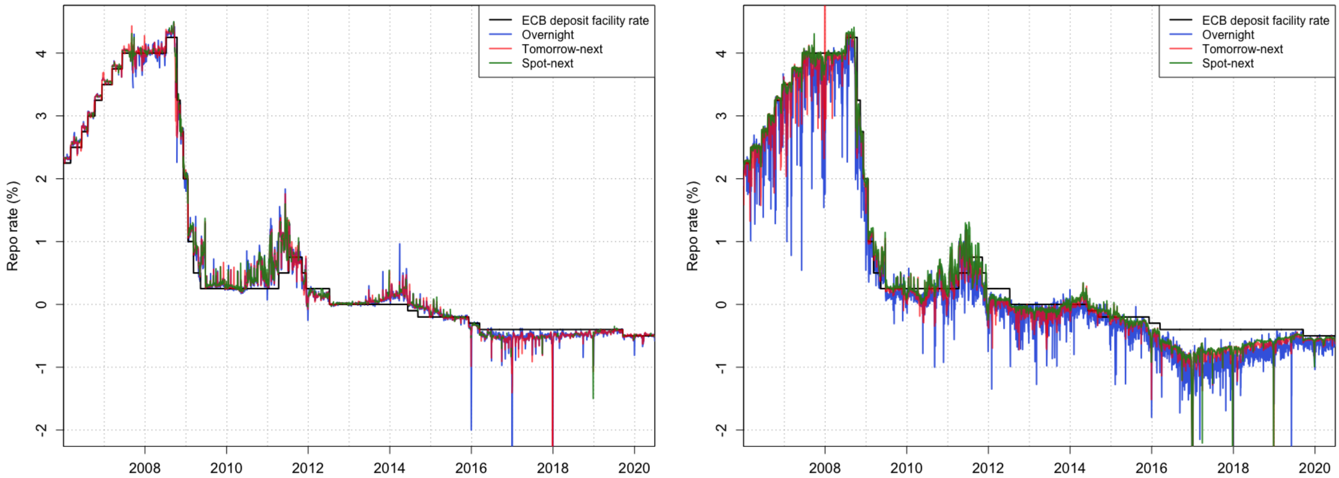
While the GCX and GCP segments can be estimated with ordinary least squares (OLS) as they each represent individual time series, the GC and SC regressions require a different approach. Consider the specials: each day, we observe repo transactions with various ISINs as collateral. Previous studies have derived a single special rate (e.g. by taking a volume-weighted average over all bonds) and tested the EH using these rates. However, doing so inserts a bias. As can be seen in eq. (4), the test requires three different rates (as we are testing the EH in differences). If these rates by calculating averages over different compositions of bonds (as they certainly are), then noise is inserted into our estimation of the coefficient. Counter-intuitively, this noise biases the OLS estimate to *zero*, making it more likely to reject the null hypothesis that $\beta = 1$. It is thus crucial to match our data such that for each observation, we compare a forward premium and a target (Δr_{t+1}) which are derived on the basis of the exact same ISIN (or basket, in the case of the GCs). Thus, for the GC and SC segments, we run a pooled OLS model as follows: $\Delta r^b_{t+1} = \alpha + \beta_1 \cdot s^b_t + u_{t+1}$. We calculate rates as daily volume-weighted averages across baskets and ISINs, respectively, and cluster our standard errors along those dimensions.[6] We run these regressions for each of the three cases (i.e. the different combinations of TN/SN rates predicting ON/TN rates at our disposable).

Several conclusions emerge. First, we fail to reject the weak form of the EH (i.e. where we allow $\alpha \neq 0$) for the GCX and GCP baskets. Indeed, the β coefficient is impressively close to 1. This tells us that for repo segments where specialness is not a factor, the expectations hypothesis cannot be rejected. On the other hand, both GC and SC segments see the EH rejected. Second, we see that the performance of the EH monotonically decreases as we go from less to more special segments. This can best be seen by combining the α and β coefficients; in case (iii) we see that the GCX segment is (as expected) best-performing with a value of 0.968. The GC segment is still at a decently high level of 0.922, but the SC segment sees a clear

[6] Alternatively, we could run a fixed effects panel regression model. This would allow for ISIN-specific (basket-specific) term premia for the SC (GC) repos. Instead, by running pooled OLS with an intercept, we impose a common term premium for each segment.

		GCX	GCP	GC	SC
	α	-0.011***	-0.010***	-0.007***	-0.061***
		(0.001)	(0.001)	(0.001)	(0.003)
Case (i): TN/ON	β	0.993	0.976	0.909***	0.633***
		(0.034)	(0.033)	(0.026)	(0.003)
	$\alpha + \beta(1)$	0.982	0.966	0.902	0.572
	R^2	0.791	0.708	0.600	0.328
	Obs.	2'605	3'629	12'593	21'315
	α	-0.011***	-0.012***	-0.013***	-0.098***
		(0.002)	(0.002)	(0.002)	(0.009)
Case (ii): SN/ON	β	0.996	0.991	0.868**	0.823**
		(0.037)	(0.036)	(0.063)	(0.076)
	$\alpha + \beta(1)$	0.985	0.979	0.855	0.725
	R^2	0.621	0.619	0.438	0.528
	Obs.	2'256	2'729	3'403	20'703
	α	-0.002	-0.003***	-0.002*	-0.010***
		(0.001)	(0.001)	(0.001)	(0.001)
Case (iii): SN/TN	β	0.970	0.965	0.924***	0.686***
		(0.030)	(0.025)	(0.015)	(0.024)
	$\alpha + \beta(1)$	0.968	0.962	0.922	0.676
	R^2	0.697	0.694	0.668	0.325
	Obs.	2'219	2'686	18'957	682'116

Table 1: The regressions for the GCX and GCP segments are OLS with Newey-West standard errors. The GC and SC models are pooled OLS with standard errors clustered by basket and ISIN, respectively. The superscripts $***$, $**$ and $*$ indicate significance at 1%, 5% and 10% significance level respectively and test the null hypothesis of $\alpha = 0$ and $\beta = 1$. For GCX and GCP baskets, rates are daily averages across transactions. For the GC and SC segments, rates are daily volume-weighted averages across baskets and ISINs, respectively. The data sample extends from January 2^{nd}, 2006, to June 30^{th}, 2020. The last week of the calendar year is dropped due to strong outliers.



(a) German general collateral (GC) rates **(b)** German special collateral (SC) rates

Figure 1: Panels (a) and (b) plot three maturities of German general and special collateral repo rates, respectively. Rates are calculated as the daily volume-weighted average across transactions.

rejection of the EH with 0.676. Similarly, the R^2s of the regression models decreases as we go to more special segments.

The discrepancy between special and general repos' performance in the EH is clear and can be observed visually. Figure (1) plots volume-weighted average GC and SC rates for repos collateralised by German bonds. Each maturity (ON, TN, SN) is plotted separately. Looking at panel (b), we see that the maturities are juxtaposed to each other, and that this dynamic holds true over the whole sample. To the contrary, the GC rates of panel (a) directly overlap and are clearly on the same level throughout the sample. We further observe the classic dichotomy between special rates and non-special rates, whereby special rates trade at a discount due to collateral value. This is essentially a clear visualisation of a time series where the EH holds and one where it does not. The question then is why do such rates consistently differ when they are collateralised, traded in liquid markets, and have such very short maturities ?

In the traditional theory of the term structure of interest rates, term premia represent a risk premium that risk-averse investors demand for holding long-term bonds.[7] Investors earn this premium because the short-term return earned from

[7] Cohen, Hördahl, and Xia (2018) provide a review of the theory and estimation methodology

holding a long-term bond is risky, but it is certain if a bond is maturing over that same horizon. In this sense, the absence of term premia at any maturity, as documented by Longstaff (2000), makes sense in GC repo. Generally, in perfectly functioning and frictionless markets, term premia are assumed to be constant over time, as this would otherwise open up arbitrage opportunities such as those modelled in Vayanos and Vila (2021). However, in reality bond premia are impacted by supply and demand effects, for example caused by central bank bond purchases as part of quantitative easing, or due to maturity-specific fixed income demand from pension funds and insurance companies. This is the fundamental concept behind the preferred habitat theory of the term structure, as pioneered by Modigliani and Sutch (1966) and Vayanos and Vila (2021).

Our results indicate that term premia in repo markets are solely related to participants' desire to obtain a specific collateral, as opposed to needing liquidity per se. It is highly unlikely that the premia are related to cash lending, as we observe no similar dynamics in the GC segment. Therefore, we could posit either (i) a time-varying risk premium which explains the EH underperformance in the special sector, or (ii) a preferred habitat effect driving a wedge between these interest rates. This paper will principally focus on the second motivation.

5 Experiment: shortening the settlement cycle

5.1 Dynamics of the T+2 shift

The divergence in EH performance that we observe in general and special repos can be explained by the fact that the two are cash and collateral driven, respectively. We hypothesise that the latter segment in particular is affected by preferred habitat effects stemming from the unique role special repos play w.r.t. to the underlying collateral. This focus on preferred habitat effects is in contrast to the extant literature, which has thus far focussed on the presence of time-varying risk premia as a potential explanation.

of bond term premia, upon which I rely here.

We leverage a quasi-experiment set-up to identify a habitat consisting of traders who operate at the intersection of the repo and bond markets. To do so, we identify a specific segment of the repo market which serves as the "bridge" to the cash market.[8] Our identification strategy takes advantage of a regulatory reform which changed the settlement time of fixed income markets. The settlement cycle refers to the time settlement takes for the transaction of financial instruments including equities, bonds, and so forth. The standardisation and shortening of the settlement cycle alleviates counterparty risk and decreases clearing capital requirements as well as reducing pro-cyclical margin and liquidity demands. Crucially, the European Union used to have a T+3 settlement standard until it moved to T+2 settlement on October 6$^{\text{th}}$, 2014 (ICMA, 2014; PricewaterhouseCoopers LLP, 2015).[9]

Notably, even though the regulatory reform only impacted *bond* markets, we observe major and seemingly corresponding shifts in activity in *repo* markets. The l.h.s. of Figure (2) plots the evolution of tom-next and spot-next special volumes and pinpoints the time when Europe transitioned its settlement cycle. TN daily trading volumes increase dramatically from 10B to as much as 40B. The SN segment experiences a corresponding drop in absolute value, from 150B to 120B, although it recovers around two years later. Both of these shifts occurred precisely on the date of the reform.[10] The ON volumes (not shown here) stay constant.

These dynamics are a first indication of a link between the repo and cash markets. A further piece of evidence is provided by considering the corresponding effects in the cash-driven segment; general repo is plotted in the r.h.s. of Fig (2). The T+2 change does not perceptibly impact the GC market. This highlights the role of the special spot-next (and subsequently, tom-next) segment as the bridge between

[8] The fixed income market (or bond market) is frequently referred to as the cash market when comparing it to the repo market. The cash market can further be split into the primary and secondary segments, depending on whether the bond sold is newly issued or not.

[9] Exceptions were Germany, which was already on a T+2 schedule, and Spanish equities, which migrated during the fourth quarter of 2015. Foreign exchange settlement was already T+2. The U.S. used T+3 settlement since 1995, switched to T+2 on September 5$^{\text{th}}$, 2017, and updated to T+1 on May 28$^{\text{th}}$, 2024.

[10] Interestingly, German repos also show these dynamics, even though German bonds were apparently already transitioned to T+2. This suggests that many German bonds trade in foreign markets.

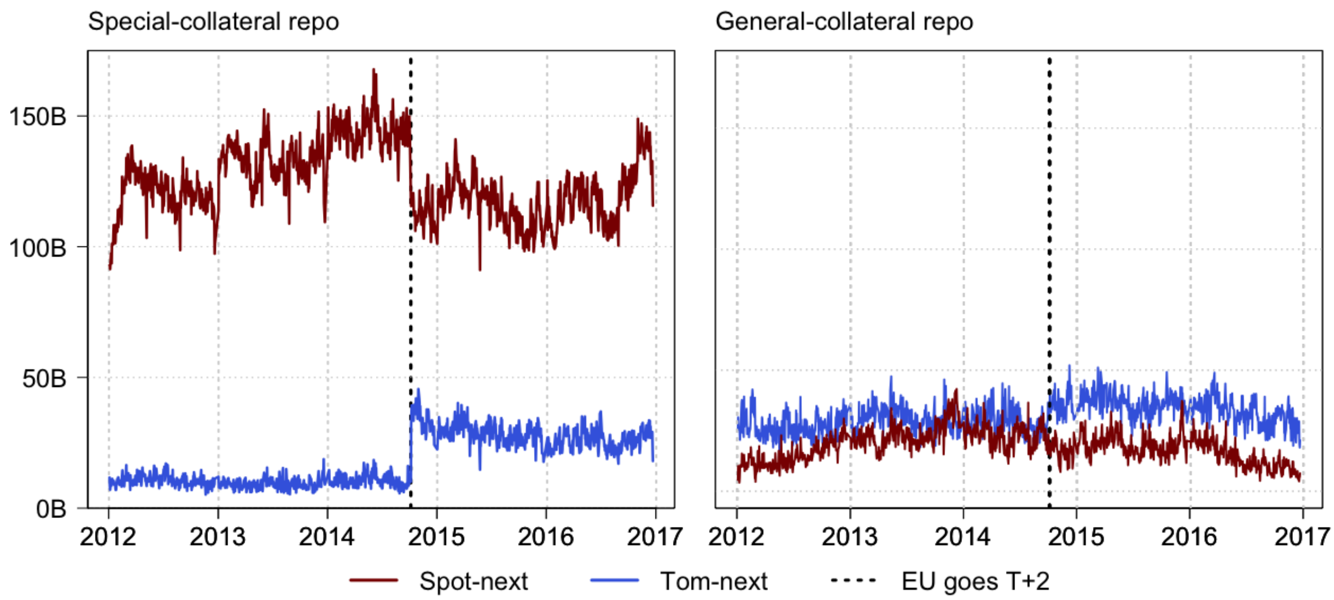


Figure 2: Daily turnover of special (l.h.s.) and general (r.h.s.) repos. The last week of each calendar year is dropped for visualization purposes.

repo and cash markets. The fact that only specials were affected indicates to us that the affected repos were collateral-driven. The fact that they adapted to the settlement time of the cash market indicates that they were used in conjunction with fixed income trades, and thus needed to be synced to that settlement cycle. The following section will further delineate the mechanism.

In Appendix D, we provide a formal econometric test of the dynamics shown in Figure (2). That is, we split our data according to its various segments (i.e. by $\{Segment \text{ x } Country \text{ x } Tenor\}$), and test that a volume shift from SN to TN indeed occurred only for special repos. The econometric model we use will be introduced in section 6.2. Results are shown in Table (D1) shows our results, which are economically and statistically significant across all specifications. They suggest that the T+2 switch caused an 85%-93 percent increase in the treated segments' volume. This confirms the results presented by our graphical evidence and emphasises there was a migration of a preferred habitat from the special spot-next segment to the special tomorrow-next segment, whereas other sectors were unaffected.

Finally, we observe a shift as to *which* bonds were traded in what segment. We calculate the number of unique ISINs on a given day which traded e.g. in the

TN segment and also traded in the ON segment. We thus calculate this number as a share of the unique collaterals which traded in the TN segment (i.e. $((B_t^{TN} \bigcap B_t^{ON})/B_t^{TN}) \cdot 100$, where B is the set of unique ISINs traded on a given day t for a given maturity m). We derive this for our three cases: TN/ON, SN/ON, and SN/TN. The three resulting time series are plotted in Figure (3).

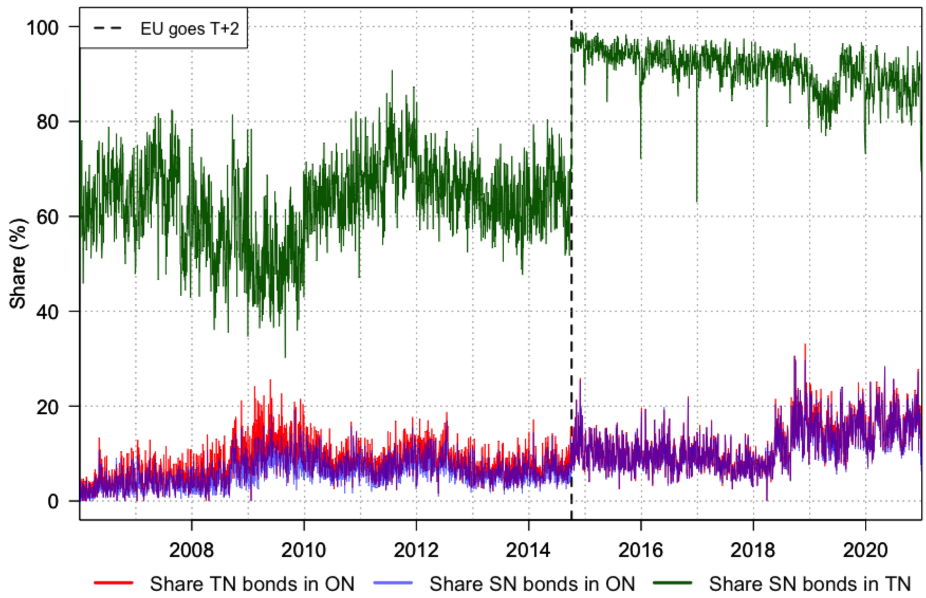


Figure 3: Share of unique collaterals traded across maturities

No particularly strong dynamics are seen for the share of TN and SN bonds overlapping with ON bonds. For the duration of the sample, these values are relatively stable with an average of 9.3% and 8.1% respectively. The two time series are heavily correlated, but this is partly mechanical, given that the ON segment is far smaller than the TN and SN (and thus bonds which appear in both TN and ON also likely appear in both SN and ON maturities). Some action is observed on the T+2 shift, but is small and temporary. On the other hand, we see a marked and permanent shift in collateral overlap in the TN/SN case on the critical date of October 6$^{\text{th}}$, 2014. On that day, the share of unique SN collaterals trading in TN (as a percentage of all unique SN collaterals) jumped from 70% to 97.4%. This suggests a large amount of collaterals which were traded in the SN segment shifted to the

TN, but that these collaterals also continued to trade in the SN habitat.

5.2 Inspecting the mechanism

The dynamics in Figure (2) represent the movement of a habitat from one segment to another. Before proceeding to an econometric test of whether this change in preferred habitat had a pricing effect, in this section we will discuss the causes and drivers of this phenomenon.

Figure (2) tells us that a share of repo transactions were timed to sync exactly with the delivery of bonds in the cash market. This is because agents frequently use repo to provide them with the liquidity and/or securities obligations they must deliver in the fixed income market. Let us proceed with an example, as depicted in Figure (4). Consider an agent buying and selling bonds throughout the day (T) before the implementation of the T+2 settlement reform. At the end of the day, they calculate their position and observe that they will purchase a certain bond on a net basis. They will now receive the bond B in three days ($T+3$) and will have a cash outflow $-C$ at that time (see the top row of the figure).

Consider now that the agent does not have the cash on hand needed to pay for the bond purchase. The next morning, the agent can resolve this by agreeing a repo, using that same bond as collateral. Given that we are now in period $T+1$ and needing to deliver the cash at $T+3$, the spot-next maturity imposes itself. The funding issue is then resolved. If the agent closes the position by selling the bond at the same time they agree the repo ($T+1$), they do not ever need pay for the bond; the bond sale will cancel out the far leg of the repo at time $T+4$ (refer to Fig. 4). While we are demonstrating a one-period example, the process could be continued. If the agent desires to hold the bond for longer, or purchases even more of the bond, he can perform another repo at time $T+2$ to roll over the trade. Again, the agent need not ever purchase the bond, and can continue holding it until its eventual sale.

The bottom half of Fig. (4) should make it clear why participants then shifted to the tomorrow-next maturity after the $T+2$ reform. Previous to the reform,

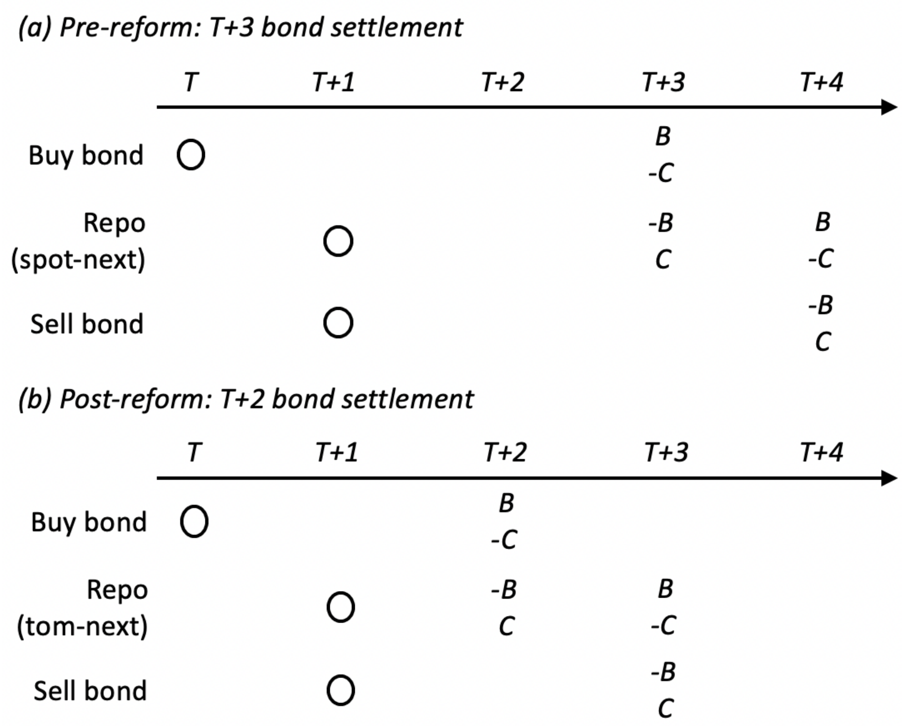


Figure 4: Financing a cash position (leveraging). Circles represent when a trade is agreed. B and C refers to the delivery of a bond or cash, respectively. The graphic denotes how an agent would finance a cash position before and after the T+2 settlement reform.

a spot-next repo was necessitated to provide cash funding for a bond purchased at time T; after the reform, tom-next became the "bridge" to the cash market. We will explain why doing so in the special segment (as opposed to the general) is preferable later in this section.

Fig. (4) demonstrates the financing of a cash position. Economically, this is equivalent to *leveraging*. The agent has taken a position on a bond with a self-financing strategy. The resulting profits are of the order $\Delta P^B_{T+4,T+3} - r^{SN}_{T+1}$, or $\Delta P^B_{T+3,T+2} - r^{TN}_{T+1}$ in the post-reform period (recall that repo rates have been negative since 2012, thus the rate component is actually positive). The inverse operation is also possible of course: participants can cover an outgoing securities position. If an agent has committed to sell a bond at time $T+3$, they can perform a *reverse* repo; everything works the same, but as a mirror image of Fig. (4). Figure (5) shows these dynamics for completeness. Such a process is correspondingly equivalent to short-selling; profits are of the order $-\Delta P^B_{T+4,T+3} + r^{SN}_{T+1}$, or $-\Delta P^B_{T+3,T+2} + r^{TN}_{T+1}$ in the post-reform period.

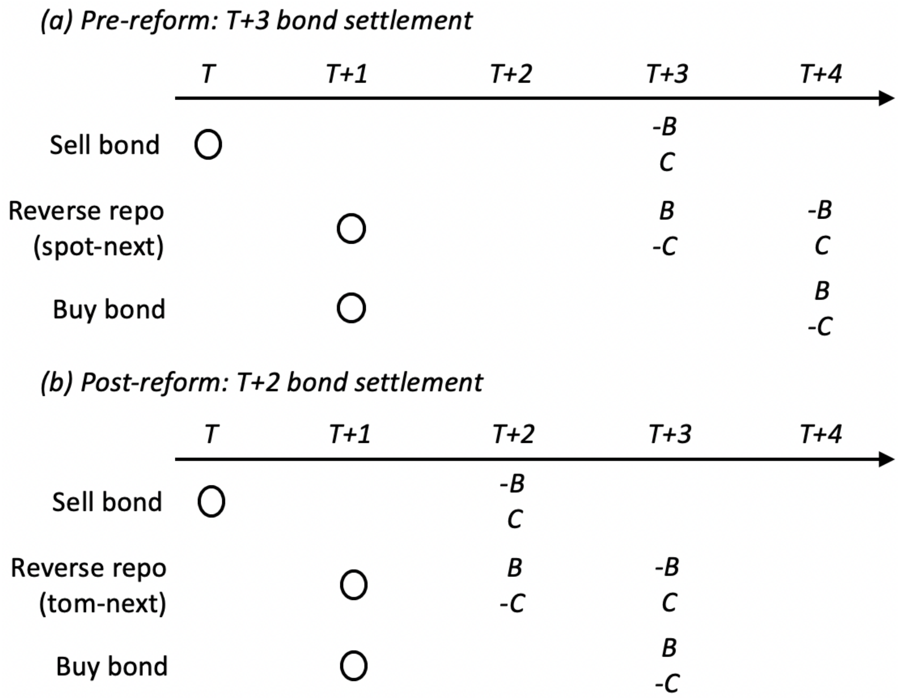


Figure 5: Covering a securities position (short-selling). Circles represent when a trade is agreed. B and C refers to the delivery of a bond or cash, respectively. The graphic denotes how an agent would cover a securities position before and after the T+2 settlement reform.

Why do traders wait one day to (reverse) repo away their exposure?[11] The answer has much to do with the schedule of the market. Interviews with traders have indicated to us that participants only know their net position once it is calculated at the end of the day. Then, liquidity is at its lowest, and finding a specific bond may be difficult and/or costly. They instead wait for the next day's more liquid morning hours to net the previous day's imbalance (on intraday patterns, see e.g. Dufour, Marra, and Sangiorgi, 2019). Indeed, in anticipation of the settlement reform, the International Capital Market Association (ICMA, 2014) as well as the European Repo Council and the International Securities Lending Association, predicted that after the shift, repos would "most likely move to $T + 1$ [i.e. a tom-next maturity].

[11] For example, an actor could at time T instigate a repo with a near leg at $T+3$ and a far leg at $T + 4$; such a maturity is called "corporate-next" (CN). While we observe a significant shift from SN to TN maturities in our data, we see no corresponding shift from CN to SN. ON, TN, and SN maturities comprise 94.5% of repos; that the CN tenor sees very little relative daily turnover may also be part of the answer.

This is because the cash positions that need to be financed and the securities positions that need to be covered in the SFT [securities financing transaction] markets are only known after close of business on the cash market transaction date (T)." Interestingly, a similar dynamic is observed in FX swap markets. Kloks, Mattille, and Ranaldo (2023) document that a banks' net currency exposures will be calculated at end-of-day and swapped into domestic currency the next morning, which is why a surge in tom-next FX swap turnover is observed at 8 a.m. London time.

Why do agents use the special segment, as opposed to the general, for such operations? In the case of covering a securities position, the answer is obvious: the agent must provide the specific bond in the cash market. Agreeing a general reverse repo provides no guarantee that the correct ISIN will be retrieved. In the opposite case, financing a cash outlay, the agent could potentially use the general segment. However, given the dynamics of repo specialness, this would be wasteful: special repo offers far more attractive rates, and safe asset bonds are in high demand (and were equally so in 2014). Recall Figure (1); as special repo rates are negative, an agent would be paid to borrow the missing cash if he uses a special repo!

So far, we have characterized the observed dynamics as a sign that participants use (reverse) repo to cover their positions in fixed income trading. A layman perception of banks' trading may assume that agents have cash and bond inventories to call upon to net out imbalances. This is not the case: in reality, cash/bond shortages occur on a daily basis, and are netted out in repo. We have made the point that the mechanisms demonstrated in Figures (4) and (5) are economically equivalent to leveraging and short-selling, respectively. However, it may also be the case that agents are not just covering net positions, but pursuing these strategies explicitly. Consider for example the leveraging example. If an agent has spare cash at hand after conducting the repo at time $T+1$, they could use such cash to purchase more of the bond, which they could then use in a further repo, and so forth.

Indeed, repos are often used by cash market participants to finance long bond positions or to initiate a short sale, by borrowing liquidity or the underlying asset respectively (Corradin and Maddaloni, 2020). For example, in order to short-sell a bond, a market participant must first borrow the security; one can achieve this through a reverse repo transaction. Conversely, repo transactions are often used by institutional investors to fund leveraged investment strategies on a cost-efficient basis. For example, pension fund managers who need to borrow to fund purchases of government bonds to hedge the long-term exposure of their liabilities to interest rate and inflation risks, use repo as a source of leverage (ICMA, 2019). Short-selling can also be used for reasons other than speculation on the price of the bond itself. For example, it allows market-makers to continuously quote prices for securities that they do not hold in inventory. If an investor buys one of these securities, the market-maker can be sure of being able to deliver, because they know they can borrow it if they are unable or unwilling to immediately buy that security from someone else in the market. Furthermore, short-selling enables dealers in the secondary market to hedge the interest rate risk on their inventory as well as any temporary long positions accumulated through buying.

Note that this process could in theory be used to implement infinite leverage (ICMA, 2019). In reality, credit and regulatory capital constraints such as the Basel III leverage ratio imposes a constraint on such activity (see Ranaldo, Schaffner, and Vasios (2021) for the regulatory cost of repo). Note that the presence of these dynamics does not necessarily mean that the agent is placing a speculative bet on the performance of the bond. It may be that the investor is hedging their position otherwise, e.g. through interest rate swaps or by selling futures on the bond. In such a case, the transactions would serve just to finance the bond purchase.

A final comment should be made on the feasibility of short-selling. Collateral re-use is allowed in European repo, therefore selling a collateral obtained through a repo does not cause an issue. However, "locate rule" regulations do state that parties should first ensure that they can obtain a security (through reverse repo) before selling it. The short-sale of a security without first borrowing it is termed naked or uncovered short-selling. In the EU, such activity has been banned by the "Regulation on Short Selling and Credit Default Swaps" which came into force in March 2012 (European Commission, 2012). However, the ban does not apply to market-makers or banks involved in the issuance of government bonds (ICMA, 2019). As these are the prevalent agents in our data, short-selling is a plausible motive in the trading patterns we observe.

6 Impact of the reform on the EH performance

The quasi-experimental set-up described in the previous section provides an excellent opportunity to test whether preferred habitat effects actually do exist in these short-term tenors. This would be a somewhat remarkable discovery, given that preferred habitats are frequently referred to as existing in maturities at the far-end of the yield curve, i.e. those tenors affected by quantitative easing purchases or pension fund demand, etc. Here, we are interested in testing whether a preferred habitat could exist in maturities which are all one day long, but simply have a one-day difference in settlement time. Thus, the goal of this section will be to ascertain whether the shift in habitat we observe had any impact on the EH performance.

6.1 Conditions and hypotheses

Before proceeding, let us consider the conditions required for such a pricing effect to occur, and draw up potential hypotheses. Should we expect the EH performance of the treated segment to improve or deteriorate? Why? Here we take a moment to consider the implications of a pricing effect. When considering whether the habitat shift in question will affect prices, the following three conditions must be met.

Condition 1: Agents' trades must have non-zero price impact, i.e. order flow must be able to move prices.

Consider a simplified framework whereby agents place orders T, which are either to borrow cash (B) or lend it (L). This would entail initiating a repo or reverse repo contract, respectively. The sum total of agents' cash borrowing/lending over an interval $[t, t-1]$ is the order flow $X_{t,t-1}$. A regression of the price, in this case the repo rate $r_{t,t+1}$, on order flow yields the Kyle (1985) lambda.

$$X_{t,t-1} = \sum_{k=t-1}^{t} \mathbb{1}[\mathrm{T_k} = \mathrm{B}] \; - \; \mathbb{1}[\mathrm{T_k} = \mathrm{L}], \tag{5}$$

$$\Delta r_{t,t-1} = \lambda \cdot X_{t,t-1} + u_{t,t-1} \tag{6}$$

If agents in the repo market were to have zero price impact, there would naturally be no pricing effect despite the shift in habitat. Buying or selling pressure could not impact the pricing dynamic even if order flow were lop-sided. If the Kyle lambda in eq. (6) is zero and markets are perfectly liquid and efficient, we would observe no effect. This is unlikely to be the case, but is not entirely theoretical either (for example, a market where prices are pinned down by a no-arbitrage principle should see relatively little to no price impact).

Condition 2: Repo buying and selling pressure do not cancel out.

Condition 1 points out that if $\lambda = 0$ in eq. (6) then order flow cannot impact the price. Similarly, if order flow itself $X_{t,t-1} = 0$, then we can expect no price change. For that not to occur, we must have

$$\sum_{k=t-1}^{t} \mathbb{1}[\mathrm{T_k} = \mathrm{B}] \; \neq \sum_{\mathrm{k=t-1}}^{\mathrm{t}} \mathbb{1}[\mathrm{T_k} = \mathrm{L}] \tag{7}$$

Naturally, if the buying and selling pressure of repo contracts cancels out, then we would observe no net pricing effect, even if agents have a positive price impact. In our setting, we have two types of agents who changed habitat at the T+2 transition date: those who were financing cash outlays, and those who were covering their bond positions. For simplicity, we refer to these as leveragers and short-sellers respectively. Leveraging requires borrowing cash, hence initiating a repo transaction (B) while short-selling necessitates a reverse repo (L). Thus Condition 2 states that no pricing effect will be observed if the share of leveragers equals the share of short-sellers in the transferred habitat.

If short-sellers dominate, we would expect the EH to improve. Short-sellers perform reverse repos and thus bid down the rate of the segment they trade in. Thus, if short-selling is the dominant motive, we would expect the special TN rate to decrease relative to the SN; given that the forward premium consistently over-shoots target (as shown in Table (1)), we would expect this to improve the EH performance. On the other hand, if leveragers (who bid up the rate through their outright repo trades) dominate, we would expect the TN rate to increase relative to the SN, and for the EH performance to worsen. Of course, there is no guarantee that there is a dominant group at all, in which circumstance we would expect no change in the EH performance.

Condition 3: The spread caused by the transition of the preferred habitat is not arbitraged away.

This condition is at the core of preferred habitat theory. Even if Conditions 1 and 2 hold, agents outside of the shifted habitat could enter the market and arbitrage any resulting spread. In preferred habitat theory, arbitrageurs are risk-neutral and unable to take on the interest rate / duration risk required to arbitrage long-term maturity mismatches. This particular reason is unlikely to hold in our case, given that the maturities in our experiment are all one-day. Thus Condition 3 stipulates that an impediment to arbitrageurs' activity is required for there to be a pricing effect.

Conditions 1-3 must all hold for us to see an impact on the EH performance. Conversely, if we observe a directional pricing impact, we can surmise that all three have been fulfilled. We summarize our potential hypotheses below. Note that in the case the EH performance remains constant, we unfortunately cannot identify whether it is hypothesis (c) or (d) which has been validated.

(a) The EH performance improves, because short-sellers dominate the transferred preferred habitat (all conditions hold).

(b) The EH performance deteriorates, because leveragers dominate the transferred preferred habitat (all conditions hold).

(c) The EH performance stays constant, because the effects of short-selling and leveraging cancel each other out (condition 2 is not met).

(d) The EH performance stays constant because the preferred habitat theory has no effect, for example because there is no price impact, or because arbitrageurs can step in (either condition 1 or 3 is not met).

6.2 Difference-in-difference-in-differences estimation

We may now finally proceed to testing the performance of the EH before and after the T+2 change. Figures (2) indicates several routes to a difference-in-differences analysis. The l.h.s. panel suggests that comparing relative EH performance in GC and SC rates before and after the T+2 change would satisfy the parallel trends assumption. Our treatment group would be the EH performance of TN special rates, and we would compare them to the unaffected TN general results. However, this leaves us open to the possibility that GC and SC rates may have evolved differently for reasons other than the 2014 T+2 change. To remove this possibility, we would like another control group allowing us to observe the relative GC and SC performance where they are both unaffected by the treatment. The SN segment can precisely play this role. We could thus run a difference-in-differences analysis comparing the special TN and SN performance before and after the T+2 change, but this would equivalently open us up to the possibility that other factors than the treatment could impact the relative performance of TN and SN maturities.

This motivates our usage of the difference-in-difference-in-differences (DDD) estimator, which combines the two difference-in-differences set-ups into one econometric specification. The DDD model is a strictly superior approach as it does not require either of the aforementioned parallel trends assumptions.[12] The required assumption is relatively weak: it requires that the relative EH performance of special repos w.r.t. general repos in the tom-next maturity does not trend differently from the relative EH performance of special repos w.r.t. general repos in the tom-next matu-

[12] See Wooldridge (2010) and Olden and Møen (2022) for a discussion of the conditions necessary for the usage of the DDD estimator.

rity, outside of the T+2 shock. A potential objection may be that the control group should not be affected by the shock itself, and clearly the switch to T+2 affected all repos (as the change actually occurred in the bond market). However, we are not interested in the T+2 change itself, but rather the surge in volume, and the habitat contained therein, and this effect clearly manifested itself only in the special tom-next segment.

For estimation purposes, we must be able to estimate the performance of the EH at a given point in time. Equation (4) decomposes the EH failure into a time-constant and time-varying risk-premia; as it requires a full time series it is unsuitable. Instead, we need a measure of the EH hypothesis that can be estimated for each given day in our sample (so that it may be used as a dependent variable). Furthermore, we need to ensure that the underlying collateral b (be it a basket in the general case, or an ISIN in the SC special segment) is identical for both the predictor and target rate. To do this, we simply calculate the EH error as the difference between the predicting rate and the target rate, for a given collateral type. A further challenge is posed by the fact that we need to standardize the EH error as a share of the underlying rate. The rates in our sample vary widely from e.g. below -2% to over 4% (see Fig. (1)). As taking a percentage of a zero percent interest rate is impossible, we re-scale the rates by taking their absolute value and adding 1. Thus, we define our EH error as:

$$\xi_t^{b,n} := \frac{r_t^{b,n} - r_{t+n-m}^{b,m}}{1 + |r_{t+n-m}^{b,m}|} \tag{8}$$

where n is the predictor rate and m is the target rate (in this case it is always the ON rate). To summarise, our identification set-up essentially compares the relative abilities of the TN and SN rates to predict the ON rate in the general vs. special segments, before and after the T+2 shift. Appendix E provides a graphical schema of our econometric model. Our regression now considers a multitude of $\{Segment$ x $Country$ x $Collateral$ x $Tenor\}$ time series. Each EH error stemming from a GC (SC) repo with a specific basket (ISIN) is a unique observation. Note that when considering a DDD model with various time periods and segments, a full set of corresponding dummies can be added to eq. (9); see Wooldridge (2010). These fixed effects render all but three interaction variables redundant through perfect multicollinearity. We consider both versions of the model:

$$\xi_t^{b,n} = \beta_1 \cdot D_t^{SC} + \beta_2 \cdot D_t^{TN} + \beta_3 \cdot D_t^{SC} \cdot D_t^{TN} + \delta_0 \cdot D_t^{T+2} + \delta_1 \cdot D_t^{T+2} \cdot D_t^{SC} + \delta_2 \cdot D_t^{T+2} \cdot D_t^{TN} + \delta_3 \cdot D_t^{T+2} \cdot D_t^{SC} \cdot D_t^{TN} + \beta \cdot \mathbf{X} + \alpha + u_t^{b,n} \quad (9)$$

$$\xi_t^{b,n} = \delta_1' \cdot D_t^{T+2} \cdot D_t^{SC} + \delta_2' \cdot D_t^{T+2} \cdot D_t^{TN} + \delta_3' \cdot D_t^{T+2} \cdot D_t^{SC} \cdot D_t^{TN} + \beta' \cdot \mathbf{X} + \omega + \tau + u_t^{b,n} \quad (10)$$

where $\mathbf{X}$ is a set of control variables and ω are $\{Segment \text{ x } Country \text{ x } Collateral \text{ x } Tenor\}$ fixed effects. Our controls are the current level of the overnight rate on the date the forecast repo is traded (i.e. to control for the level of the interest rate) and the lagged EH error for that particular grouping. These controls will have little to no bearing on our regression coefficients. The coefficient of interest then is $\hat{\delta}_3$, which has the interpretation:

$$\hat{\delta}_3 = \left\{ \left(\hat{\xi}_{\text{SC, TN, T+2}} - \hat{\xi}_{\text{SC, TN, T+3}} \right) - \left(\hat{\xi}_{\text{SC, SN, T+2}} - \hat{\xi}_{\text{SC, SN, T+3}} \right) \right\} - \left\{ \left(\hat{\xi}_{\text{GC, TN, T+2}} - \hat{\xi}_{\text{GC, TN, T+3}} \right) - \left(\hat{\xi}_{\text{GC, SN, T+2}} - \hat{\xi}_{\text{GC, SN, T+3}} \right) \right\} \quad (11)$$

We now run various specifications of regression models (9) and (11) in table (2). We run our model first on data from the 6-year period around the T+2 implementation (which we call our "proximate" sample), as well as on the full sample. Given the length of our sample (15 years' worth of data), we expect that the effect we describe here may have attenuated over time. On the other hand, considering the full sample gives us more statistical power. We include only $\{Segment \text{ x } Country \text{ x } Collateral \text{ x } Tenor\}$ series which appeared before and after the T+2 switch. For all specifications, we drop all observations which occur during the final week of each calendar year, as well as any observations where $|\xi_t^{b,n}| > 100$. We also run with specifications where we winsorize the data at the 2.5% and 97.5% level.[13]

[13] The winsorization is carried out separately per $\{Segment \text{ x } Tenor\}$ combination. Our results

The performance of the EH is negatively impacted across the board; the error increases by 3-4% when considering our 6-year proximate sample. The result is weaker when considering the full sample, suggesting that the dynamics we observe attenuated over time or were counter-acted by other factors in later years. Note that our coefficient results are under-estimated due to the operation we conducted in eq. (8). When re-running the analysis on the unscaled EH error (i.e. the numerator of eq. (8)), we obtain an effect size of 5-7 basis points.

Before proceeding to the economic interpretation of our results, we proceed to a final robustness check of our specification, which is placebo testing. In order to ensure that our econometric specification is working as intended, in Appendix F we re-run the models of Table (2) on placebo dates for the T+2 treatment effect. That is to say, we repeat the exact same exercise, but see how our results evolve when we assume a date two years prior, and two years after, to the actual T+2 implementation date of October 6^{th}, 2014. When considering our proximate, 6-year samples, we now take the 3 years before and after the respective placebo dates. Therefore Table (F1) re-runs our models with a placebo date of October 6^{th}, 2012, and Table (F2) does the same for a date of October 6^{th}, 2016.

None of the DDD estimators from the combined 16 placebo test specifications achieve statistical significance. The economic magnitudes are small and occasionally incorrectly signed. Note that when running these placebo tests on the full sample many of the observations are actually correctly labelled, outside of the 2 years where we shifted the placebo date. Nevertheless, these placebo tests confirm that the T+2 shift which occurred on October 6^{th}, 2014 indeed had a causal impact on the performance of the EH in short-term rates.

7 Interpreting our results

The worsening of the EH performance in the treated segment provides evidence in favor of hypothesis (b): that preferred habitat theory can impact short-term rates,

are robust to even stronger winsorizations.

	Expectations hypothesis error: $\xi_t^{b,n}$							
	Proximate sample				Full sample			
	Raw		Winsorized		Raw		Winsorized	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SC	11.507***		11.150***		8.168***		8.842***	
	(0.717)		(0.622)		(0.589)		(0.443)	
TN	−0.094		−0.117		−0.536***		−0.416***	
	(0.134)		(0.153)		(0.125)		(0.125)	
T2	1.060***		0.284		−0.466*		−0.922***	
	(0.343)		(0.212)		(0.253)		(0.148)	
SC:TN	−5.063***		−4.775***		−2.792***		−2.571***	
	(1.045)		(0.833)		(0.767)		(0.518)	
TN:T2	−0.040	0.088	−0.002	0.136	0.412**	0.328*	0.319*	0.326*
	(0.215)	(0.175)	(0.158)	(0.121)	(0.192)	(0.185)	(0.173)	(0.174)
SC:T2	−3.646***	−3.621***	−3.652***	−3.392***	−2.604***	−3.616***	−2.791***	−3.085***
	(0.751)	(0.827)	(0.646)	(0.707)	(0.577)	(0.663)	(0.443)	(0.491)
SC:TN:T2	3.993***	3.385***	3.620***	2.984***	1.857**	1.815**	1.524**	1.429**
	(1.158)	(1.159)	(0.925)	(0.961)	(0.836)	(0.890)	(0.604)	(0.650)
$\xi_{t-1}^{b,n}$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
r_t^m	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	α	$\omega+\tau$	α	$\omega+\tau$	α	$\omega+\tau$	α	$\omega+\tau$
Clustering	ω	$\omega+\tau$	ω	$\omega+\tau$	ω	$\omega+\tau$	ω	$\omega+\tau$
Obs.	23,005	23,005	23,005	23,005	38,224	38,224	38,224	38,224
R^2	0.140	0.027	0.195	0.020	0.112	0.029	0.158	0.021

Table 2: Odd-numbered specifications run the model in eq. (9); evens that of eq. (11). *SC* denotes whether the repo is collateralised by a special, *TN* denotes whether the repo is tomorrow-next (as opposed to SN or ON), *T2* equals 1 if the repo occurred after the shift to T+2 settlement. α refers to *Country*, ω to {*Segment* x *Country* x *Collateral* x *Tenor*}, and τ to *Trade Date*. For all specifications, we drop all observations on the last week of the calendar year as well as all where $|\xi_t^{b,n}| > 100$. We further remove all ω combinations which did not trade both before and after the T+2 switch. Winsorized data is adapted at the 2.5% and 97.5% levels per {*Segment* x *Tenor*} combination. The within-model R^2 is reported.

and that leveragers dominate the transferred habitat. Both of these results merit discussion.

Our findings show that preferred habitat theory can have an effect in habitats with the same maturity, but which differ only in settlement times by one day. Furthermore, we have shown this effect in a heavily traded, deep, and liquid market. Thus, our results indicate that preferred habitat effects are more powerful and pervasive than previously believed. While comparing the proximate and full sample results in Table (2) suggests that the spread did attenuate over time, the evidence presented here suggests that the ON, TN, and SN rates each operate - to a certain extent - as their own habitat. This is remarkable given that they each have the exact same tenor (from leg to leg) but differ only in their settlement times.

It is difficult to suggest that arbitrageurs' risk aversion blocks them from closing these spreads; given the near-identical nature of the respective segments, issues like interest rate risk are hardly a factor. Instead, the likely culprit is an inability to access the safe assets required for the reverse repos needed to close these spreads. Arbitrageurs should be performing spot-next special-collateral reverse repos, but doing so requires arbitrageurs to have the requisite safe asset collateral. Safe asset scarcity caused by unconventional monetary policy and/or inelastic pension fund demand ensures that they do not.

Second, our results highlight the prevalence of leveraging in repo. Note that when we use the term leveraging, we are referring to the practice of financing a cash position as previously discussed. But it is also plausible that the more explicit form of leveraging is also at play, as there is precedent for this in repo markets. Buraschi and Menini (2001) give the example of Orange County, California which, in an attempt to earn high non-tax income, took positions worth \$20 billion, using just \$7.5 billion of assets, by financing themselves in repo. More recently, Schrimpf, Shin, and Sushko (2020) explore how the Covid-19 crisis resulted in a forced sell-off of US Treasury securities by investors who had attempted to exploit small yield differences through the use of repo leverage. They further argue that these investors could achieve high levels of leverage because the collateral value of Treasury securities is normally very high: "For instance, if an investor can borrow \$99 by pledging \$100 worth of Treasuries, the investor need have only \$1 of own funds to hold Treasuries worth \$100, achieving 100-fold leverage." At the time of writing, the potential for high levels of leverage in repo still attracts attention and concern from central banks and regulators; see for example Barth, Kahn, and Mann (2023).

Given our discussion of safe assets and convenience yields in section (2), one can see why leveraging using special repos would be attractive. For one, doing so allows investors to achieve high rates of leverage by obtaining cheap repo funding, as just discussed. Second, many financial intermediaries are now flush with quality assets, which are readily available to be lent out.[14] Imagine an entity with €100 of quality German bunds on its books. It could lend these bonds and receive say €99 of funding, with which it could then buy further bunds on the bond market, which could then be again lent out, etc. Indeed, in the era of zero or negative interest rates which started in 2012, such an investor would receive *more* cash than the value of the collateral they provided (see Figure (1))!

In an environment of negative interest rates, safe assets, and convenience yields, it is perhaps unsurprising that such strategies are popular. Special rates trade lower than their general counterparts; as short-selling requires a reverse repo, the agent is lending cash at a suboptimal rate. In particular, borrowing special bonds is particularly cumbersome in the safe asset environment. Leveraging, on the other hand, means the agent could take advantage of a security they own, while borrowing at cheap special rates. Indeed we identified the profitability of leveraing and short-selling to be $\Delta P^B_{T+3,T+2} - r^{TN}_{T+1}$ and $-\Delta P^B_{T+3,T+2} + r^{TN}_{T+1}$ respectively. Given the presence of negative interest rates, it is easy to see why the former is advantageous w.r.t. the latter. Interestingly, the desire to leverage positions in certain bonds *decreases* the specialness of those bonds; the repo transactions required for leveraging

[14] Note that while legal ownership of the collateral changes hands during a repo agreement, the benefits of such collateral (e.g. any coupon payments due during the term of the repo) accrue (somewhat counter-intuitively) to the collateral's original owner, i.e. the cash-borrower.

bid up the special rate in equation (12).

Note that our results are remarkable in that we identify an economically significant change in the EH performance (around 5% of target) based the difference between two counter-acting exogenous shocks. That is, it is the *difference* between the share of leveraged trades and short-sale trades which is causing this 5% shift. Our average treatment effect is not the effect of a shift in e.g. just leveragers or short-sellers, but the effect caused by the delta between the two. This speaks favorably to the strength of our results (or alternatively, to the strong dominance of leveraging in this market). This motivates our need to understand the share of leveragers to short-sellers, which we analyze below.

We run a few further experiments to confirm our intuitions. First, our conclusion that leveragers outnumbered short-sellers in the transferred habitat suggests that we would expect a stronger order flow going into repos (as opposed to reverse repos). For each transaction in our data, we are able to identify whether the transaction was initiated by the party committing a repo or reverse repo transaction. We can thus define our order flow measure ϕ per maturity and collateral as the share of volume in which the initiator (or "aggressor") borrowed cash. We run models as in equations (9) and (11), with our measure of order flow aggressiveness as our dependent variable. We run the specifications once on the raw shares and once on logarithmic values (to get a percentage change). As before, we include the lagged dependent variable as well as the level of the interest rate being traded as controls.[15]

Our results in Table (3) show a statistically and economically significant increase in order flow aggressiveness in the treatment group after the T+2 switch. Note that given that our dependent variable in the "raw" specification is bounded by (0,1), we are de facto running a linear probability model. In any case, the regression results confirm that order flow into repos (reverse repos) increased (decreased), which is consistent with our story that leveragers dominated this preferred habitat. We also

[15] A larger number of observations are reported in this specification as we previously could only use observations for which we had both a predictor and a target rate with the same collateral available.

	Order flow aggressiveness $\phi_t^{b,n}$							
	Proximate sample				Full sample			
	Raw		Logarithmic		Raw		Logarithmic	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SC	−0.039*		−0.210***		−0.037*		−0.233***	
	(0.022)		(0.052)		(0.019)		(0.067)	
TN	0.038**		−0.042		0.030**		−0.056	
	(0.017)		(0.049)		(0.012)		(0.056)	
T2	0.014		0.036		0.044**		0.045	
	(0.017)		(0.042)		(0.019)		(0.040)	
SC:TN	−0.082***		−0.250***		−0.099***		−0.363***	
	(0.029)		(0.069)		(0.027)		(0.117)	
TN:T2	−0.034	−0.037	−0.109	−0.125	−0.022	−0.025	−0.032	−0.050
	(0.029)	(0.031)	(0.075)	(0.080)	(0.028)	(0.030)	(0.061)	(0.068)
SC:T2	−0.023	−0.027	−0.124**	−0.143**	−0.044**	−0.046**	−0.096	−0.115
	(0.019)	(0.021)	(0.050)	(0.054)	(0.021)	(0.022)	(0.065)	(0.071)
SC:TN:T2	0.068**	0.074*	0.244**	0.267**	0.082**	0.087**	0.320***	0.357***
	(0.034)	(0.036)	(0.099)	(0.105)	(0.037)	(0.039)	(0.096)	(0.106)
$\phi_{t-1}^{b,n}$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
r_t^m	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	α	$\omega+\tau$	α	$\omega+\tau$	α	$\omega+\tau$	α	$\omega+\tau$
Clustering	ω	$\omega+\tau$	ω	$\omega+\tau$	ω	$\omega+\tau$	ω	$\omega+\tau$
Obs.	49,885	49,885	49,885	49,885	106,370	106,370	106,370	106,370
R^2	0.121	0.061	0.104	0.025	0.123	0.059	0.145	0.042

Table 3: Odd-numbered specifications run the model in eq. (9); evens that of eq. (11). *SC* denotes whether the repo is collateralised by a special, TN denotes whether the repo is tomorrow-next (as opposed to SN or ON), $T2$ equals 1 if the repo occurred after the shift to T+2 settlement. α refers to *Country*, ω to {*Segment* x *Country* x *Collateral* x *Tenor*}, and τ to *Trade Date*. For all specifications, we drop all observations on the last week of the calendar year. The within-model R^2 is reported.

similarly run placebo tests based on the proximate sample (not shown here) and confirm that only the T+2 switch is capable of rendering this result.

Finally, as discussed a by-product of the mechanism at hand is that repo specialness should have *decreased* in the treatment group following this switch. This may seem counter-intuitive at first, given that leveragers are essentially betting on an increase in value of safe asset collateral. However, by bidding up the repo rate, leveragers are mechanically decreasing specialness in the repo market. Recall that we measure specialness as a spread to the GCP rate, and further scale it as in eq. (8). For a repo with underlying bond b and maturity m, we thus have:

$$\gamma_t^{b,m} := \frac{r_t^{\{\text{b=GCP}\},m} - r_t^{b,m}}{1 + |r_t^{\{\text{b=GCP}\},m}|} \tag{12}$$

Note that b in equation (12) can refer to either a basket or an ISIN, depending on whether or not we are referring to a GC or SC repo. Given that we lose a control group (as we can only use repos for which we can calculate specialness), we run a simple difference-in-differences model as follows:

$$\gamma_t^{b,m} = \beta_1 \cdot D_t^{TN} + \beta_2 \cdot D_t^{T2} + \beta_3 \cdot D_t^{TN} \cdot D_t^{T2} + \beta_4 \cdot \gamma_{t-1}^{b,m} + \beta_5 \cdot r_t^{GCP,m} + b + u_t^{b,m} \tag{13}$$

$$\gamma_t^{b,m} = \beta_3' \cdot D_t^{TN} \cdot D_t^{T2} + \beta_4' \cdot \gamma_{t-1}^{b,m} + \beta_5' \cdot r_t^{GCP,m} + \omega + \tau + u_t^{b,m} \tag{14}$$

where b are collateral fixed effects. We run the model twice, once basing the specialness variables on the GCP rate (as shown) and once based on the GCX.

Table (G1) in Appendix G shows our results; they point to a consistently significant decrease in repo specialness of around 1.5% (2%) when considering specialness relative to the GCP (GCX) basket. By leveraging their bets on special bonds in fixed income markets, leveragers decrease the specialness of those bonds in repo markets. Naturally, one presumes that the securities these leveragers buy in bond markets increase in price due to their bidding, while their repo activity decreases their value as collateral.

8 Conclusion

Repo markets are an ideal laboratory to test the expectations hypothesis. While results on this critical question have thus far been mixed, this study clarifies that the major distinguishing factor in the validity of the EH in repo is whether we are running the test on general or special collateral segments. We find that the EH fails in special repos, despite the fact that we carefully match collaterals of the exact same ISIN.

We posit the existence of a preferred habitat connecting the repo segment to fixed income markets. Leveraging a quasi-exogenous experiment in the reform of settlement times in bond markets, we show that a large portion of the repo market is used to fund positions in the cash market. When this segment transferred to the tomorrow-next maturity along with the new shortened settlement time, the tom-next maturity increased on average and thus its performance in EH tests declined relative to special spot-next trades. The general collateral segment provided an opportune second control group, allowing us to use a powerful and robust difference-in-difference-in-differences specification. We further saw that as a result of these changes, order flow aggressiveness increased and treated repo specialness decreased.

Three noteworthy results stand out. First, we show that the EH can indeed hold in the ideal setting of general collateral, and is thus not just a theoretical construct. Second, we show that preferred habitat effects are more powerful and pervasive than previously thought. The tom-next and spot-next maturities which were affected here have the same maturity and differ only in settlement time by one day. This is a far cry from preferred habitat theories which have analysed differences in tenors with years' distance from each other on the yield curve. Finally, we show that repo markets are used to finance unfunded cash/securities outlays and to take on leveraged positions. We suggest that the convenience yields of safe assets allow for cheap repo funding, which may encourage such behaviour. Our results thus contribute to the literature on the expectations hypothesis and preferred habitat phenomena, while also shedding light on a potential financial vulnerability.

The cash borrower performs a repo, while the cash lender (bond borrower) is conducting a reverse repo. Legal ownership of the collateral changes hands, but the benefits of such collateral (e.g. any coupon payments due during the term of the repo) accrue to the collateral's original owner, i.e. the cash-borrower. In the example below, the repo rate is calculated as (10199)/99 = 2%. The cash lender is likely to apply a haircut to the loaned amount. In this case the haircut is 1-99/100 = 1%.

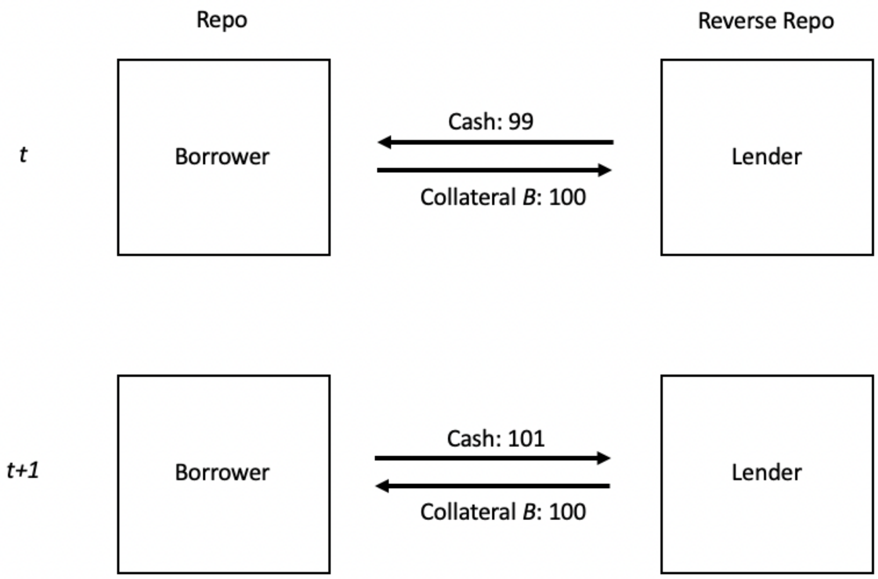


Figure A1: Example of a repo transaction

Panel A: GC Repo Rates								
	DE	FR	BE	NL	ES	IT	GCP	GCX
GC ON Repo Rates								
Mean	0.576	0.190	0.476	0.320	-0.021	-0.127	0.728	0.017
Std Dev	1.455	1.013	1.357	1.252	0.574	0.581	1.511	0.504
Min	-8.000	-7.222	-3.093	-3.635	-1.805	-0.490	-1.011	-0.944
Max	4.488	4.439	4.650	4.400	4.350	4.100	5.117	2.975
Obs	3'421	3'125	3'111	2'641	2'328	269	3'679	2'797
GC TN Repo Rates								
Mean	0.686	0.118	0.694	0.472	0.060	0.032	0.706	−0.002
Std Dev	1.522	0.868	1.486	1.336	0.715	0.537	1.494	0.491
Min	−4.009	-3.339	-3.459	-3.452	-1.618	-0.727	-1.583	−0.549
Max	4.480	4.410	4.500	4.530	4.060	4.070	4.955	3.050
Obs	3'702	3'036	3'431	3'247	2'521	2'723	3'575	2'665
GC SN Repo Rates								
Mean	0.715	-0.027	0.343	0.082	-0.022	0.032	0.283	−0.042
Std Dev	1.379	0.542	0.913	0.940	0.450	0.526	1.041	0.435
Min	-4.177	-4.012	-4.000	-3.868	-1.263	-0.656	-1.353	-0.550
Max	4.500	4.385	4.460	4.330	3.550	3.310	4.488	2.900
Obs	1'554	1'624	417	379	1'496	2'736	2'697	2'303

Panel B: SC Repo Rates						
	DE	FR	BE	NL	ES	IT
SC ON Repo Rates						
Mean	0.376	0.151	0.328	0.049	−0.062	0.228
Std Dev	1.506	1.191	1.394	1.174	1.078	1.288
Min	-7.706	-5.000	-6.732	-8.025	-6.499	-5.010
Max	4.297	4.310	4.350	4.401	4.300	4.360
Obs	3'650	698	3'332	2'884	3'124	929
SC TN Repo Rates						
Mean	0.523	0.559	0.609	0.588	0.599	0.343
Std Dev	1.539	1.508	1.530	1.537	1.511	1.193
Min	-7.663	-4.336	-7.059	-8.468	-1.515	-1.236
Max	7.624	4.310	4.347	4.388	4.402	4.390
Obs	3'707	1'871	3'706	3'706	3'707	3'287
SC SN Repo Rates						
Mean	0.588	0.802	0.656	0.632	0.645	0.677
Std Dev.	1.553	1.578	1.529	1.536	1.503	1.490
Min	-5.481	-2.250	-4.749	-4.974	-1.014	-0.960
Max	4.410	4.313	4.432	4.405	4.410	4.450
Obs	3'707	1'951	3'707	3'707	3'707	3'685

The below graphic displays a stylised depiction of various tenors. Circles represent when the trade is agreed (and hence, the time at which the expection governing the rate was formed). Dotted lines represent when the loan / repo was active (i.e. when interest was being paid). (a) shows a multi-period compound interest rate in the style of equation (1), where $n = 2$. (b) does the same for two short-term rates where $m = 1$. (c)-(e) show the dynamics of ON, TN, and SN repos respectively, and align them so that a test of the EH could be made for the time period at time t.

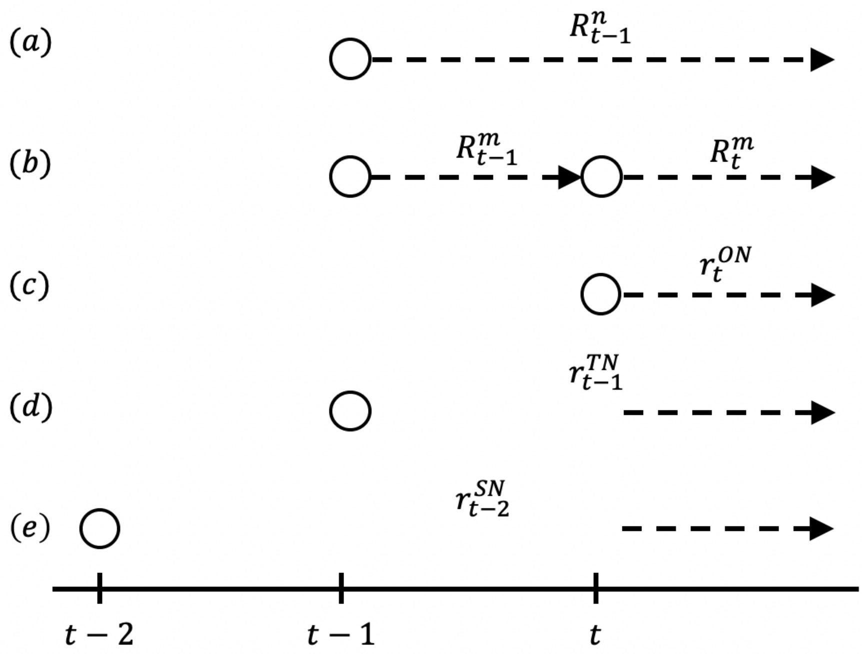


Figure C1: Visualisation of various maturity types

We validate the hypothesis formed in section 5.1 and confirm econometrically to ourselves that a significant trading volume shift occurred from spot-next to tom-next occurred for special (but not general) repos. We run a DDD model using traded volume V as our dependent variable; this is essentially a formal econometric confirmation of the dynamic we observe in Fig. (2). We split our trading volume data into several time series according to $\{Segment \text{ x } Country \text{ x } Tenor\}$. For example, we consider the trading volume of special French repos in the overnight tenor, to make a time series denoted $\{SC \text{ x } FR \text{ x } ON\}$. Given that we have 2 segments, 8 countries, and 3 maturities, we end up considering 34 different time series.[16] We run:

$$V_t \;=\; \beta_1 \cdot D_t^{SC} \;+\; \beta_2 \cdot D_t^{TN} \;+\; \beta_3 \cdot D_t^{SC} \cdot D_t^{TN} \;+\; \delta_0 \cdot D_t^{T+2} \;+\; \delta_1 \cdot D_t^{T+2} \cdot D_t^{SC} \;+\; \delta_2 \cdot D_t^{T+2} \cdot D_t^{TN} \;+\; \delta_3 \cdot D_t^{T+2} \cdot D_t^{SC} \cdot D_t^{TN} \;+\; \alpha \;+\; u_t \tag{15}$$

where D denotes a dummy variable, SC denotes whether the repo is collateralised by a special, TN denotes whether the repo is tomorrow-next (as opposed to SN or ON), $T + 2$ equals 1 if the repo occurred after the shift to T+2 settlement, and α here represents country fixed effects. $\hat{\delta}_t$ then is the DDD estimator, giving us a causal estimate of the impact of the settlement change on trading volumes. We further consider a specification with a comprehensive set of fixed effects:

$$V_t \;=\; \delta_1' \cdot D_t^{T+2} \cdot D_t^{SC} \;+\; \delta_2' \cdot D_t^{T+2} \cdot D_t^{TN} \;+\; \delta_3' \cdot D_t^{T+2} \cdot D_t^{SC} \cdot D_t^{TN} \;+\; \lambda \;+\; \tau + \; u_t \tag{16}$$

where we use $'$ to distinguish our coefficients from the full specification, λ refers to $\{Segment \text{ x } Country \text{ x } Tenor\}$ fixed effects, and τ refers to time fixed effects. To isolate the effect of the treatment, we run our two models on data extending one year before, to one year after, the date of the T+2 switch. Finally, we also consider these two specifications in logged volumes, in order to get a consistent percentage change in trading volume across segments.

Table (D1) shows our results. The DDD estimator is economically and statis-

[16] Given that we treat GCP and GCX as "countries", and that we remove 8 time series for insufficient data, the calculation is $(2 \cdot 8 \cdot 3) - (2 \cdot 3) - 8 = 34$.

	Volume (B)		Volume (logs)	
	(1)	(2)	(3)	(4)
SC	14.645**		0.655	
	(6.323)		(0.950)	
TN	0.293		0.509**	
	(1.650)		(0.198)	
T2	−0.524		−0.017	
	(0.441)		(0.100)	
SC · TN	−15.571**		−0.707	
	(6.803)		(0.978)	
TN · T2	1.462**	1.443**	0.248	0.234
	(0.632)	(0.625)	(0.169)	(0.168)
SC · T2	−2.356*	−2.174	0.086	0.128
	(1.310)	(1.289)	(0.179)	(0.178)
SC · TN · T2	5.346***	5.183**	0.658**	0.617**
	(2.064)	(2.053)	(0.290)	(0.289)
Fixed effects	α	$\lambda + \tau$	α	$\lambda + \tau$
Clustering	λ	$\lambda + \tau$	λ	$\lambda + \tau$
Obs.	16'686	16'686	16'686	16'686
R^2	0.261	0.190	0.058	0.059

Table D1: Specifications (1) and (3) run the model in eq. (15); (2) and (4) that of eq. (16). *SC* denotes whether the repo is collateralised by a special, TN denotes whether the repo is tomorrow-next (as opposed to SN or ON), $T+2$ equals 1 if the repo occurred after the shift to T+2 settlement. α refers to *Country*, λ to $\{$*Segment* x *Country* x *Tenor*$\}$, and τ to *Trade Date*. The within-model R^2 is reported.

tically significant across all specifications. The logged-volume regressions suggest that the T+2 switch caused an 85%-93%[17] increase in trading volume (while high, Figure (2) saw TN volumes surge from below 10 to 40 billion). This confirms the results presented by our graphical evidence and emphasises there was a migration of a preferred habitat from the special spot-next segment to the special tomorrow-next segment, whereas other sectors were unaffected.

[17] As the model is in log-linear form, a unit increase in the regressor causes a $100 \cdot \left(e^{\delta} - 1\right)$ percent increase in the dependent variable.

The below figure helps visualize the different tenors and segments used in our empirical model. General-collateral repos were unaffected by the shift, as was the spot-next segment. Thus spot-next special repos are the only pure treatment group. We use overnight rates as the target. Two difference-in-difference models are available to us: one comparing general and special tom-next repos, and one comparing special spot-next and tom-next repos. The difference-in-difference-in-differences model combines both into one econometric specification. It is a strictly better model as it requires a far weaker parallel trends assumption.

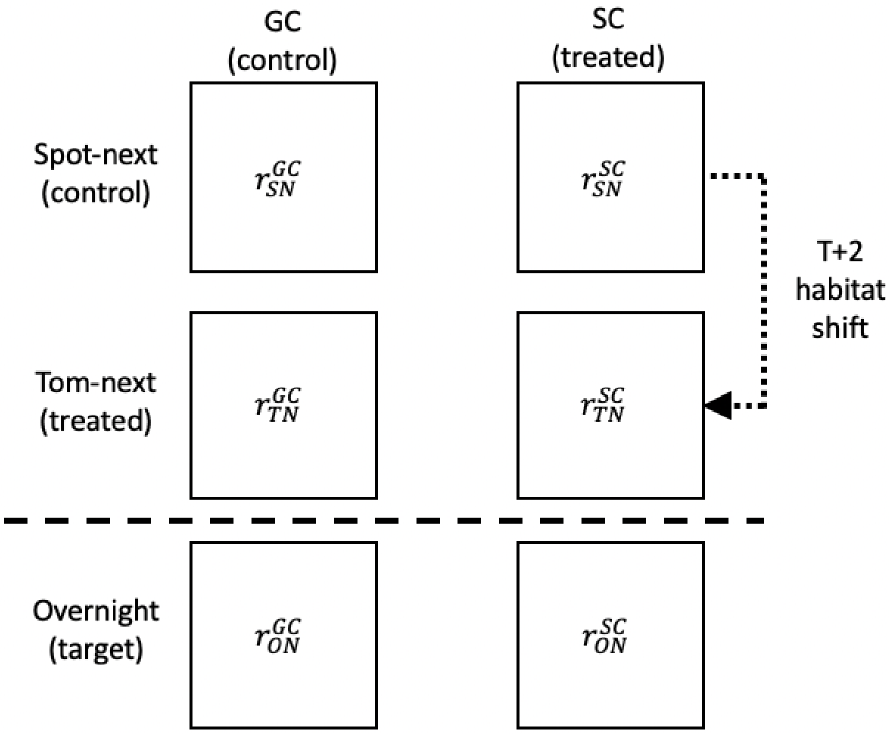


Figure E1: Empirical model schema

	Expectations hypothesis error: $\xi_t^{b,n}$ on placebo date of October 6th, 2012							
	Proximate sample				Full sample			
	Raw		Winsorized		Raw		Winsorized	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SC	9.269***		9.497***		6.943***		7.391***	
	(0.939)		(0.737)		(0.723)		(0.499)	
TN	−0.762***		−0.584**		−1.088***		−0.757***	
	(0.269)		(0.250)		(0.227)		(0.175)	
T2′	0.873***		0.207		−0.465		−0.749***	
	(0.315)		(0.194)		(0.368)		(0.210)	
SC:TN	−2.857***		−3.197***		−1.906**		−2.182***	
	(1.079)		(0.807)		(0.909)		(0.566)	
TN:T2′	0.985***	0.763***	0.773***	0.566*	1.048***	0.707***	0.711***	0.514*
	(0.176)	(0.263)	(0.184)	(0.291)	(0.265)	(0.251)	(0.191)	(0.275)
SC:T2′	1.075	0.710	0.355	0.270	−0.714	−0.977	−1.297***	−1.095*
	(0.814)	(1.060)	(0.614)	(0.877)	(0.688)	(0.811)	(0.435)	(0.571)
SC:TN:T2′	0.397	−0.070	0.813	0.243	0.515	0.664	0.822	0.843
	(1.150)	(1.333)	(0.891)	(1.087)	(0.962)	(1.041)	(0.611)	(0.738)
$\xi_{t-1}^{b,n}$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
r_t^m	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	α	$\omega+\tau$	α	$\omega+\tau$	α	$\omega+\tau$	α	$\omega+\tau$
Clustering	ω	$\omega+\tau$	ω	$\omega+\tau$	ω	$\omega+\tau$	ω	$\omega+\tau$
Obs.	18,958	18,958	18,865	18,865	38,224	38,224	38,224	38,224
R^2	0.137	0.032	0.177	0.014	0.109	0.026	0.156	0.019

Table F1: We assume a placebo date of October 6, 2012 for the T+2 switch, resulting in variable $T2'$. Odd-numbered specifications run the model in eq. (9); evens that of eq. (11). *SC* denotes whether the repo is collateralised by a special, *TN* denotes whether the repo is tomorrow-next (as opposed to SN or ON), $T2'$ equals 1 if the repo occurred after the shift to the false T+2 settlement date. α refers to *Country*, ω to {*Segment* x *Country* x *Collateral* x *Tenor*}, and τ to *Trade Date*. For all specifications, we drop all observations on the last week of the calendar year as well as all where $|\xi_t^{b,n}| > 100$. We further remove all ω combinations which did not trade both before and after the T+2 switch. Winsorized data is adapted at the 2.5% and 97.5% levels per {*Segment* x *Tenor*} combination. The within-model R^2 is reported.

	Expectations hypothesis error: $\xi_t^{b,n}$ on placebo date of October 6th, 2016							
	Proximate sample				Full sample			
	Raw		Winsorized		Raw		Winsorized	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SC	7.758***		6.934***		7.309***		7.508***	
	(0.389)		(0.328)		(0.407)		(0.330)	
TN	−0.065		−0.125		−0.419***		−0.294**	
	(0.131)		(0.120)		(0.126)		(0.125)	
T2″	−0.027		−0.443**		−0.427*		−0.662***	
	(0.254)		(0.190)		(0.236)		(0.185)	
SC:TN	−1.383***		−1.273***		−1.828***		−1.912***	
	(0.468)		(0.411)		(0.471)		(0.372)	
TN:T2″	0.028	0.232	0.075	0.257	0.359*	0.307	0.258	0.277
	(0.168)	(0.230)	(0.178)	(0.185)	(0.217)	(0.212)	(0.216)	(0.194)
SC:T2″	−1.666***	−1.262***	−1.276***	−0.933**	−2.291***	−1.910***	−2.385***	−1.897***
	(0.463)	(0.485)	(0.418)	(0.426)	(0.451)	(0.489)	(0.404)	(0.420)
SC:TN:T2″	0.272	0.004	0.182	−0.138	0.843	0.504	0.872	0.479
	(0.654)	(0.628)	(0.585)	(0.563)	(0.635)	(0.634)	(0.554)	(0.560)
$\xi_{t-1}^{b,n}$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
r_t^m	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	α	$\omega+\tau$	α	$\omega+\tau$	α	$\omega+\tau$	α	$\omega+\tau$
Clustering	ω	$\omega+\tau$	ω	$\omega+\tau$	ω	$\omega+\tau$	ω	$\omega+\tau$
Obs.	23,375	23,375	23,107	23,107	38,224	38,224	38,224	38,224
R^2	0.147	0.015	0.182	0.022	0.113	0.027	0.164	0.021

Table F2: We assume a placebo date of October 6, 2016 for the T+2 switch, resulting in variable $T2''$. Odd-numbered specifications run the model in eq. (9); evens that of eq. (11). *SC* denotes whether the repo is collateralised by a special, TN denotes whether the repo is tomorrow-next (as opposed to SN or ON), $T2''$ equals 1 if the repo occurred after the shift to the false T+2 settlement. α refers to *Country*, ω to {*Segment* x *Country* x *Collateral* x *Tenor*}, and τ to *Trade Date*. For all specifications, we drop all observations on the last week of the calendar year as well as all where $|\xi_t^{b,n}| > 100$. We further remove all ω combinations which did not trade both before and after the T+2 switch. Winsorized data is adapted at the 2.5% and 97.5% levels per {*Segment* x *Tenor*} combination. The within-model R^2 is reported.

	Repo specialness $\gamma_t^{b,m}$							
	Proximate sample				Full sample			
	$\gamma_t^{\{b=GCP\},m}$		$\gamma_t^{\{b=GCX\},m}$		$\gamma_t^{\{b=GCP\},m}$		$\gamma_t^{\{b=GCX\},m}$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
T2	-2.412^{***}		-4.159^{**}		-1.938^{***}		-2.985^{***}	
	(0.818)		(1.758)		(0.310)		(0.935)	
TN	2.011^{***}		2.723^{***}		1.455^{***}		2.383^{***}	
	(0.408)		(0.596)		(0.299)		(0.516)	
T2:TN	-1.541^{**}	-1.437^{**}	-2.357^{***}	-1.840^{**}	-1.004^{**}	-1.355^{**}	-2.022^{***}	-1.919^{**}
	(0.623)	(0.709)	(0.914)	(0.923)	(0.447)	(0.582)	(0.735)	(0.856)
$\gamma_{t-1}^{b,n}$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$r_t^{GCP,m}$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	b	$\omega+\tau$	b	$\omega+\tau$	b	$\omega+\tau$	b	$\omega+\tau$
Clustering	ω	$\omega+\tau$	ω	$\omega+\tau$	ω	$\omega+\tau$	ω	$\omega+\tau$
Obs.	42,064	42,064	41,386	41,386	67,151	67,151	59,757	59,757
R^2	0.570	0.535	0.492	0.473	0.556	0.518	0.484	0.460

Table G1: Odd-numbered specifications run the model in eq. (13); evens that of eq. (14). TN denotes whether the repo is tomorrow-next (as opposed to SN or ON), $T2$ equals 1 if the repo occurred after the shift to T+2 settlement. b refers to *Collateral*, ω to $\{$*Segment* x *Country* x *Collateral* x *Tenor*$\}$, and τ to *Trade Date*. For all specifications, we drop all observations on the last week of the calendar year. We further remove all ω combinations which did not trade both before and after the T+2 switch. The within-model R^2 is reported.

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