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Wholesale Funding Dry-Ups

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ABSTRACT

We empirically explore the fragility of wholesale funding of banks, using transaction-level data on short-term, unsecured certificates of deposit in the European market. We do not observe a market-wide freeze during the 2008 to 2014 period. Yet, many banks suddenly experience funding dry-ups. Dry-ups predict, but do not cause, future deterioration in bank performance. Furthermore, during periods of market stress, banks with high future performance tend to increase reliance on wholesale funding. We therefore fail to find evidence consistent with adverse selection models of funding market freezes. Our evidence is in line with theories highlighting heterogeneity between informed and uninformed lenders.

TO FINANCE THEMSELVES, BANKS RELY ON deposits and wholesale funding. The latter includes repurchase agreements, interbank loans, and debt securities sold on financial markets, often with short-term maturities. A prevailing view among economists and regulators is that wholesale funding is vulnerable to sudden stops, or dry-ups, during which banks lose funding regardless of their credit quality. Such breakdowns have major macroeconomic consequences, as they may force banks to cut lending (Iyer et al. (2014)) and affect real outcomes such as unemployment (Chodorow-Reich (2014)). To mitigate this concern, new regulatory liquidity ratios penalize the use of wholesale funding (Tarullo (2014)).

In this paper, we empirically investigate the determinants of the fragility of wholesale funding markets. Most theories of market freezes are based on information asymmetries between lenders and borrowers. Among these theories, two classes of models make opposite predictions about the causes of wholesale funding market breakdowns. The first class of theories assumes that all

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lenders are equally uninformed. When lenders become concerned about the quality of borrowing banks, interest rates increase for both high- and low-quality banks. This induces high-quality banks to self-select out of the market (Akerlof (1970), Stiglitz and Weiss (1981), Myers and Majluf (1984)). Therefore, when investors are uninformed but homogeneous, funding dry-ups are driven by demand: high-quality banks stop borrowing from the market.

A second strand of theories rests on the idea that some lenders are informed. In times of stress, uninformed participants expect informed lenders to cut funding to low-quality banks, and may then prefer to stop lending altogether (Gorton and Pennacchi (1990), Calomiris and Kahn (1991), Dang, Gorton, and Holmström (2012)). In these models, funding dry-ups are driven by supply: they predominantly affect low-quality banks, which lose funding from both informed and uninformed investors. High-quality banks may lose funding from uninformed investors, but manage to keep funding from informed ones.

Since the two theories make opposite predictions about the quality of banks experiencing dry-ups, distinguishing between them is useful to understand the main frictions at work in wholesale funding markets. Distinguishing between the two theories can also have important policy implications, although such implications are beyond the scope of the current paper to explore in detail. While standard adverse selection models suggest that disclosure about issuer quality is beneficial, proponents of theories based on the presence of some informed investors emphasize potential benefits of opacity in financial markets (Holmström (2015), Dang et al. (2017)). The idea behind this policy prescription is that liquidity is enhanced when ignorance about fundamentals is mutually shared, as information disclosure may reduce risk-sharing opportunities and eventually lead to market breakdowns.

We test the competing predictions of these two theories using novel data on a large yet neglected segment of the European wholesale funding market—the market for certificates of deposit (CDs). CDs are unsecured short-term debt securities issued by banks and bought mostly by money market funds.[1] Our sample consists of more than 80% of the market for euro-denominated CDs. It covers a large segment of the wholesale funding market, with the amount of debt outstanding around EUR 400 Bn, which is comparable to the repo market and about 10 times as large as the unsecured interbank market. Our data include characteristics of 1.4 million issues by 276 banks from 2008 to 2014. We match these issuance data with issuer characteristics from Bankscope and market data from Bloomberg.

Using these data, we identify a number of *wholesale funding dry-ups*, which we define as instances in which a given bank's CDs outstanding falls to zero (full dry-up) or drops by more than 50% over the course of 50 days (partial dry-up). We isolate 75 such events between 2008 and 2014, of which 29 are full dry-ups. Based on observable characteristics, banks that experience dry-ups have on average lower profitability, more impaired loans, higher book leverage,

[1] Bank CDs are the counterpart to commercial paper issued by nonfinancial corporations (Kahl, Shivdasani, and Wang (2015)).

and a lower creditworthiness than other banks. This is in line with evidence from the market for asset-backed commercial paper (Covitz, Liang, and Suarez (2013)). Importantly, the CD market did not experience any global freeze and dry-ups did not have a strong aggregate component. This is quite remarkable, given that CDs are unsecured and our sample period includes both the financial crisis and the European sovereign debt crisis.

We next show that banks experiencing dry-ups are those whose performance is set to decrease in the future, controlling for current performance. This result casts doubt on the idea that high-quality banks self-select out of the CD market due to asymmetric information in their relation with lenders. It is instead consistent with the idea that low-quality banks lose funding from both informed and uninformed lenders. Using stock prices, we find that dry-ups are preceded by negative abnormal returns, which is consistent with negative public information being revealed and leading uninformed investors to withdraw funding.

We reject an alternative interpretation of our findings that follows theories of runs as in Diamond and Dybvig (1983) or Goldstein and Pauzner (2005). In theory, funding dry-ups could be purely uninformed events that *cause* lower future performance, for instance, because the lack of funding forces banks to liquidate assets at fire-sale prices or to pass on valuable lending opportunities. In this case, runs can be self-fulfilling equilibria where banks lose funding even when their fundamental value is high. We address this reverse causality concern by running several tests. First, a sharp reduction in CD funding also predicts a future increase in impaired loans, a measure that is less prone to reverse causality, as loans were extended prior to the dry-up. Second, the predictive power of dry-ups on performance is not driven by banks that rely heavily on CD funding—to which a drop in CD funding may cause more harm. Third, the total assets of banks facing dry-ups remain stable in the following year, suggesting that dry-ups do not force banks to engage in fire sales.

Aside from the predictive power of dry-ups, we provide three additional results consistent with theories based on heterogeneously informed lenders. First, we show that issuers facing a dry-up experience a decrease in the maturity of new CD issues several months before the decline in CD volume. In the presence of informed investors, uninformed lenders value debt securities as long as they remain information-insensitive (Gorton and Pennacchi (1990)). In times of stress, long-term debt becomes more information-sensitive, since it is repaid later. Uninformed investors can then refuse to buy longer term CDs (Holmström (2015)). Therefore, the only way to draw uninformed funding in times of stress is by reducing maturity. This mechanism explains the pattern found in the data. Second, we show that issuers facing a dry-up almost never reenter the market. This is consistent with the fact that these issuers are no longer perceived as safe. If, instead, adverse selection were at play, high-quality banks would be expected to re-enter the market after they have been identified as such. Third, the shift from information-insensitive to information-sensitive debt should follow the arrival of public news causing uninformed lenders to revise their beliefs (Dang, Gorton, and Holmström (2012)). We show that ratings downgrades can be such public news: issuance drops significantly for issuers facing downgrades. Along the same lines, we also find that dry-ups typically occur after drops in stock prices. This is consistent with the idea that when negative public information is revealed, uninformed investors are reluctant to keep lending.

Additional results also make it possible to reject an alternative reading of our findings, under which there is no asymmetric information at all. If investors were perfectly informed, the CD market could always be cleared by adjusting interest rates. However, under this view it may become optimal for the issuer to turn to the central bank or the repo market when risk becomes too large, since interest rates for these alternative funding sources become lower. Against this view, we show that the dispersion in interest rates is limited in the CD market, suggesting that risk is not priced on a bank-by-bank basis. Furthermore, the European Central Bank (ECB) refinancing rate does not seem to truncate the distribution of CD rates on its right tail. These results are consistent with the idea that prices are not the main variable used to clear the CD market, as in theories of asymmetric information.

Finally, we complete our study by shifting focus to the "intensive margin" of CD borrowing: banks increasing or decreasing their reliance on CD funding. We show that banks increasing funding in the CD market perform better in the future, conditional on current performance. This is particularly pronounced in times of market stress, as measured by the number and size of dry-ups. This second fact is more consistent with theories based on informed lenders. If adverse selection were driving the allocation of funds, high-quality banks should reduce reliance on wholesale funding, particularly when the market is stressed. As a result, increased CD reliance should predict *lower* future performance. We find that this prediction is rejected by the data. In contrast, the positive predictive power of CD borrowing on future performance again points to the presence of informed lenders.

Related Literature

This paper primarily contributes to the literature on the workings of wholesale funding markets in times of stress. To the best of our knowledge, this is the first empirical analysis of the CD market. Most papers to date study repo markets (Gorton and Metrick (2012), Krishnamurthy, Nagel, and Orlov (2014), Copeland, Martin, and Walker (2014), Mancini, Ranaldo, and Wrampelmeyer (2015), Boissel et al. (2017)), and often find that these markets did not freeze during the recent financial crisis. In contrast to these studies, we focus on unsecured borrowing, which is arguably more fragile. Chernenko and Sunderam (2014) study the dollar funding run on European banks from the perspective of money market mutual funds and find evidence of contagion to non-European borrowers. Closer to our own study, Afonso, Kovner, and Schoar (2011) analyze the unsecured U.S. Fed Funds market during the Lehman crisis. Also related are the papers by Kacperczyk and Schnabl (2010) and Covitz, Liang, and Suarez (2013) on the fragility of the asset-backed commercial paper market during the global financial crisis, as well as the case study by Shin (2009) on Northern Rock. In contrast, we study a large cross-section of wholesale funding dry-ups over several years.

Another contribution is to test which theories of funding market breakdowns are most consistent with the data. The CD market is a good laboratory to study competing theories of wholesale funding fragility. First, as CDs are unsecured, the only source of asymmetric information between a borrower and its lender is the creditworthiness of the borrower. In secured markets, such as the repo market, the quality of the collateral can also be uncertain. Second, since most lenders in this market are money market funds, dry-ups are unlikely to be driven by lenders hoarding liquidity, as could be the case in the interbank market (Bolton, Santos, and Scheinkman (2011), Malherbe (2014)).

To our knowledge, this paper is the first to test whether asymmetric information plays a significant role in the allocation of wholesale funding. We show that pure adverse selection models—with no informed investors—have a hard time rationalizing actual patterns in wholesale funding markets: high-quality banks are both less likely to face a drop in CD funding and more likely to attract additional funding in times of stress. Instead, we provide empirical support for theories in which the presence of informed lenders explains the fragility of bank funding structure, in particular, Gorton and Pennacchi (1990) and Dang, Gorton, and Holmström (2012).[2] Our results are also consistent with models in which short-term funding serves a disciplining role (Calomiris and Kahn (1991), Flannery (1994), Diamond and Rajan (2001)). In these theories, short-term informed lenders discipline banks by threatening to withdraw funding if creditworthiness deteriorates. By highlighting the presence of informed lenders, our findings help us better understand why wholesale funding markets have proved more resilient than expected.

Finally, we stress that dry-ups are distinct from traditional bank runs. Theoretically, Calomiris and Gorton (1991) discuss how models of runs as coordination failures differ from models of bank fragility based on heterogeneously informed investors. Our finding that dry-ups concentrate on low-quality banks allows us to rule out the idea that they are random, as are runs in the Diamond and Dybvig (1983) model. Yet, even in models of nonrandom runs, coordination failures among lenders may arise (Goldstein and Pauzner (2005)). This is the case if a lender's decision to cut funding decreases the expected payoff of other lenders, therefore inducing them to also cut funding (i.e., if there are strategic complementarities). However, as discussed, we do not find evidence that funding dry-ups cause banks to default or underperform. We conclude that traditional theories of runs cannot rationalize the evidence in this paper.

We proceed as follows. Section I presents the theoretical framework. Section II describes our data and the CD market. Section III documents the absence

[2] Gorton and Ordoñez (2014) show that the incentive to produce information about previously information-insensitive debt claims can generate financial crises. Chari, Shourideh, and Zetlin-Jones (2014) and Guerrieri and Shimer (2014) also show that asymmetric information matters to understand the recent financial crisis. See also Downing, Jaffee, and Wallace (2009) for empirical evidence on asymmetric information in the market for mortgage-backed securities.

of a system-wide market freeze and describes bank-specific wholesale funding dry-ups. Section IV shows that dry-ups predict future bank performance and offers evidence against explanations based on reverse causality. Section V gives additional results consistent with theories based on heterogeneously informed lenders. Section VI shows that periods of stress are characterized by a reallocation of funds toward high-quality banks. Section VII concludes. We provide supplementary material in an Internet Appendix.[3]

I. Theoretical Discussion

We use theory to derive testable predictions.

A. Theories of Dry-Ups Based on Asymmetric Information

There are two main strands of theory on wholesale funding fragility. In a first set of models, going back to Akerlof (1970), Stiglitz and Weiss (1981), and Myers and Majluf (1984), borrowers are informed and lenders are not. Hence, market breakdowns result from adverse selection. When information asymmetries are severe, lenders increase interest rates for all counterparties. This induces high-quality borrowers to exit the market and reduces the average quality of the remaining pool of borrowers. Preemptively, high-quality banks hoard cash or liquid assets to be able to exit the market. In the context of wholesale funding markets, Heider, Hoerova, and Holthausen (2015) model this mechanism and derive two equilibria. When adverse selection is moderate, the market reaches an equilibrium with a high interest rate and low-quality borrowers only. When adverse selection further worsens, the market breaks down. Both high- and low-quality banks are left out of the market, since no interest rate is compatible with trade in the funding market.[4]

An alternative set of theories highlights that the fragility of wholesale funding arises from the presence of some informed investors. With both informed and uninformed lenders, Gorton and Pennacchi (1990) show that issuing riskless debt is optimal to attract uninformed investors and protect them against informed investors. A key feature of riskless debt is that it is information-insensitive: whenever the borrower is far from default, informed lenders cannot benefit from their superior information. As mentioned by Holmström (2015), interbank debt, repos, and CDs are prominent examples of information-insensitive securities. In this context, funding dry-ups occur when debt becomes information-sensitive, as modeled by Dang, Gorton, and Holmström (2012). Informed lenders make use of their superior information and cut funding to low-quality banks. Uninformed lenders expect this to happen, and as a result may stop lending to all banks.[5] In the end, low-quality banks lose funding

[3] The Internet Appendix may be found in the online version of this article.

[4] Their model also features a full-trade equilibrium, in which asymmetric information is low and all banks borrow at a low interest rate.

[5] Rock (1986) models a similar mechanism but focuses on new share issues, which are information-sensitive securities. In his model, uninformed investors demand a price discount to

from both informed and uninformed lenders, while high-quality banks remain financed by informed lenders. As a result, funding dry-ups predict lower future bank quality, which indicates the presence of informed lenders.

A related theory in which heterogeneous information across lenders gives rise to funding fragility is Calomiris and Kahn (1991). In calm times, uninformed lenders benefit from the presence of informed lenders since the threat of funding cuts based on superior information induces the bank to exert high effort. When fundamentals worsen, informed lenders are first to cut lending to low-quality banks and obtain a higher recovery value. Furthermore, while these funding cuts may be inefficient ex post, they are ex ante optimal, due to the monitoring benefits they provide. Importantly, both Gorton and Pennacchi (1990) and Calomiris and Kahn (1991) share the same concept of liquidity: a security is liquid as long as it is issued or traded without imposing losses on uninformed investors (see Calomiris and Gorton (1991) for a more detailed discussion). In this context, funding is cut for a given bank whenever its debt securities become more difficult to value, that is, the debt is not riskless anymore.

B. Testable Empirical Predictions

Theories of asymmetric information have in common that the arrival of negative public information makes debt securities information-sensitive. After the public release of negative information, however, the two classes of theories make opposite predictions, upon which our tests are built. Theories with equally uninformed investors predict that the relative quality of the pool of borrowers *decreases* when money markets are stressed. This is because high-quality borrowers self-select out of the market to avoid pooling with low-quality banks. As a result, by exiting the market, banks reveal that they have higher quality than investors anticipated. Stock returns are therefore expected to react positively to dry-ups (which are in fact voluntary exits). Moreover, banks facing dry-ups should display better fundamentals in the future compared to banks that remain in the market.

In contrast, theories with heterogeneously informed lenders predict that the relative quality of the pool of borrowers *increases* during stress episodes. Debt becomes information-sensitive following the release of bad public news. Thus, uninformed investors pull out of the CD market to avoid being exposed to better informed investors. When there are enough informed lenders, high-quality banks continue to borrow. As a result, under these theories, dry-ups forecast on average a deterioration in fundamentals. Furthermore, since longer term CDs get repaid later, they should become information-sensitive earlier and thus dry up first. We therefore expect the maturities of new issues to shorten prior to dry-ups. Below, we offer evidence consistent with these predictions.

participate in IPOs, to compensate for the fact that they can be at a disadvantage compared to better informed investors.

II. Data Description

Our data set covers a large part of the euro-denominated CD market. Before we describe the data, we briefly provide institutional details about this market.

A. Certificates of Deposit

CDs are short-term papers issued by credit institutions, with an initial maturity ranging between one day and one year. Unlike repo funding, these securities are unsecured. Issuance in the primary market is over-the-counter and there is typically no post-issuance trading. CDs are mainly placed to institutional investors. According to the Banque de France, more than 90% of euro-denominated CDs are purchased by money market funds. Other potential buyers include pension funds or insurance companies. The minimum principal amount is set to EUR 150,000. Furthermore, CDs can be zero-coupon or bear a fixed or variable interest rate.

To issue CDs, banks must register with the regulator and set up a "CD program." The documentation of a program specifies a number of legal characteristics that all issuances must satisfy. The advantage of issuing CDs within a program is that no additional legal documentation has to be provided to investors each time a new CD is issued, as would be the case for traditional longer term bond issues. In a given jurisdiction, an issuer typically operates one program only; an issuer may nonetheless run CD programs in multiple jurisdictions, to overcome some form of market segmentation or to borrow in different currencies.

B. Data Coverage

We obtained daily issuance data on the euro-denominated CD market for the period January 1, 2008, to December 31, 2014, from the Banque de France. All currencies combined, the French market is the largest market for CDs in Europe and the second largest worldwide (behind the U.S. market but before the London market; see Banque de France (2013)). It is the largest market for euro-denominated CDs.[6]

The aggregate size of the euro-denominated CD market is depicted in Figure 1. Over the sample period, the average daily market size, measured as the sum of all outstanding CDs, is EUR 372 Bn and the average daily amount of new issues is EUR 21.1 Bn. Even if CDs are unsecured, this market remained remarkably resilient during episodes of market stress, as shown in Figure 1.

Our data represent a large share of the euro-denominated CD market. To show this, we rely on detailed data on the largest and most liquid subsegment of the European CD market, namely, the Short-Term European Paper (STEP)

[6] CDs in a number of other currencies (e.g., USD, JPY, GBP, CHF, CAD, SGD) are also issued in the French market. Issuance activity in currencies other than the euro, however, is much more limited and is not included in our analysis.

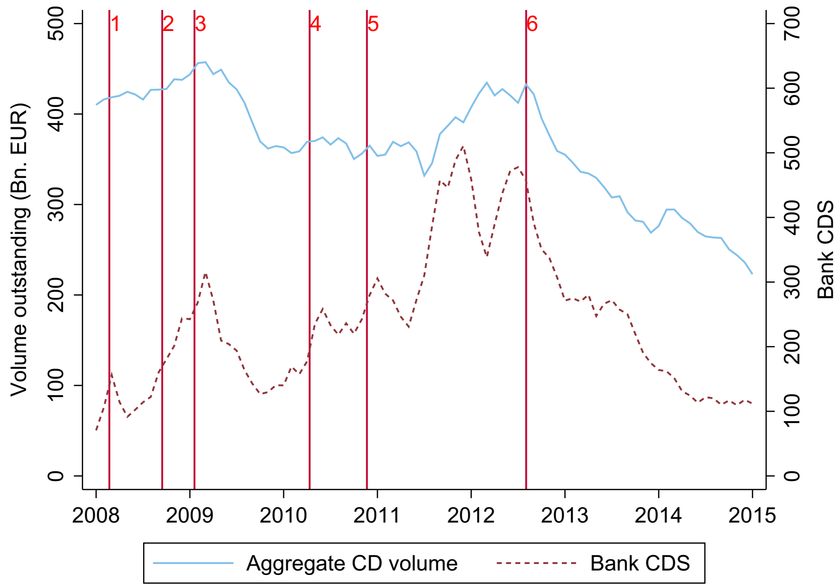

Figure 1. Size of the euro-denominated CD market. This figure displays the aggregate size of the euro-denominated CD market (solid line), as constructed from our CD issuance data, from January 2008 to December 2014. It also plots (dashed line) the spread on the five-year EU Banks Credit Default Swap (CDS) Index. Vertical lines represent six events associated with market stress: Event 1—Nationalization of Northern Rock (February 22, 2008); Event 2—Failure of Lehman Brothers (September 15, 2008); Event 3—Blue Monday crash in the United Kingdom, with the fall of Royal Bank of Scotland (January 19, 2009); Event 4—First bailout of Greece (April 11, 2010); Event 5—Bailout of Ireland (November 21, 2010); Event 6—Announcement of the Outright Monetary Transactions (OMT) by the ECB (August 2, 2012). Data are averaged at a monthly frequency. (Color figure can be viewed at wileyonlinelibrary.com)

market.[7] From the ECB, we obtain nonpublic data on the daily volume outstanding of each CD program benefiting from the STEP label. Figure IA1 in the Internet Appendix plots the breakdown of the aggregate volume of euro-denominated CDs. The French CD market is by far the largest, before the U.K. market and other markets (Belgian, Luxembourgian, etc.). Over the sample period, it represents on average 81.5% of the aggregate euro-denominated CD volume.

C. Securities and Issuer Characteristics

Our data consist of the universe of CDs issued in the French market. There are 276 individual issuers, which are described in Table I, Panel A. Among them, 71% are French and 29% are not, but they come almost exclusively from

[7] Introduced in 2006, the STEP market resulted from an initiative of market participants aimed at increasing European integration and the liquidity of the market for short-term debt securities. Financial and nonfinancial firms benefiting from the STEP label can more easily issue CDs (or

Table I

Description of the Data Set on CD Issuance

This table describes our main data set on CD issuance. Panel A describes issuers and provides a breakdown by country. Panel B displays information at the contract level. Each ISIN-level observation is associated with either an issuance, a buyback, or the cancelation of any of these operations. Each ISIN can appear multiple times in the data set, due to the buyback of previously issued CDs or to re-issuance on previously issued ISINs. Panel C describes the distribution of CD-level information for new issuances in the pooled sample. "Issued amount" is the euro amount of an individual CD in the pooled data set. "Issuances by bank" is the total number of issuances by any bank from January 2008 to December 2014. In Panel C, the minimum issued amount of EUR 100,000 corresponds to re-issuance on an existing ISIN. The minimum issued amount for new ISINs is EUR 150,000. CD data are from the Banque de France.

Panel A: Description of Issuers				
	N. Issuers	% Issuers	% Issued Amount	Largest Issuer
All	276	100.00	100.00	—
Austria	2	0.72	0.15	Oesterreichische Kontrollbank
Belgium	2	0.72	6.21	Dexia Credit Local
China	2	0.72	0.12	Bank of China
Denmark	3	1.09	0.51	Jyske Bank
France	196	71.01	72.78	BNP Paribas
Germany	12	4.35	1.03	Hypo Vereinsbank
Ireland	7	2.54	0.43	Allied Irish Banks
Italy	14	5.07	3.13	Unicredit
Japan	3	1.09	0.38	Sumitomo Mitsui
Netherlands	8	2.90	5.37	Rabobank
Spain	2	0.72	0.53	BBVA
Sweden	4	1.45	0.84	Svenska Handelsbanken
Switzerland	2	0.72	0.44	UBS
United Kingdom	11	3.98	7.36	HSBC
Others	8	2.90	1.12	—

(*Continued*)

Table I—*Continued*

Panel B: Description of CD Contracts

	N. Obs.	Frequency (%)
Number of CDs (ISINs)	819,318	—
Issuance	1,304,213	95.88
Buyback	44,482	3.27
Cancellation	11,577	0.85
Total	1,360,272	100

Panel C: Distribution of CD Characteristics

	Min.	10th	25th	Mean	Median	75th	90th	Max.
Issued amount (EUR Th)	100	180	300	51,153	900	10,000	67,850	1.36e+07
CD maturity (days)	1	2	13	66.4	33	92	181	367
Issuances by bank	1	27	125	3,072	777	2,886	7,273	106,997
Issuances by bank/week	<0.01	0.07	0.34	8.44	2.13	7.93	19.98	293.94

European countries (mainly Italy, Germany, United Kingdom, Netherlands, and Ireland). Non-French issuers account for 27.3% of all issuances. Most of the largest European commercial banks are in our data set. However, there are no Greek or Portuguese banks in the sample, due perhaps to the fact that access to the money market is restricted to high-grade issuers, consistent with Calomiris, Himmelberg, and Wachtel (1995), Covitz, Liang, and Suarez (2013), and the evidence below.

The data set contains 1,360,272 observations, which correspond to 819,318 individual securities (ISINs). After initial issuance, additional observations correspond to events that occur during the lifetime of a security, including buybacks or reissuances on the same ISIN, which are all observed. The breakdown of ISIN-level events is detailed in Table I, Panel B. Our data contain a number of security characteristics at the ISIN level, including issuance and maturity dates, the issuer's name, and the debt amount.

As seen in Table I, Panel C the distribution of issued amounts is highly skewed, with a median of EUR 900,000 and a mean of EUR 51 Mn. CDs are mostly short term, as reflected by the 33-day median maturity. The issuance frequency per bank is high, with a median of 2.1 per week and a mean of 8.4 per week.

We further match issuers with balance sheet and market characteristics, including credit ratings. We obtain balance sheet data for 263 issuers from Bankscope. We retrieve variables pertaining to banks' activity, asset quality, profitability, and capital structure. Descriptive statistics for these variables are given in Table II, Panel A. We obtain stock price and CDS spread data at a daily frequency from Bloomberg for 43 and 64 issuers, respectively. All variables are defined in Appendix Table AI.

D. CDs versus Other Wholesale Funding Instruments

European banks are the most reliant on wholesale funding worldwide, far more than U.S. institutions (see International Monetary Fund (2013) for an international comparison). To get a sense of the relative size of the euro-denominated CD market, in Figure 2 we compare its outstanding amount to three close substitutes: the repo market, the ECB's Main Refinancing Operations (MRO), and the unsecured interbank market, all measured at the Eurozone level.[8]

This benchmarking analysis clearly shows in Panel A that the CD market accounts for a large fraction of the Eurozone wholesale funding market. We see that its size is almost as large as the estimated size of the repo market—the

commercial paper) throughout Europe. See Banque de France (2013) for additional information on the STEP market.

[8] MROs are one-week liquidity-providing operations that are denominated in euros. They take the form of repurchase agreements against eligible securities. Due to their short maturity, they are a closer potential substitute for CD funding than other central bank refinancing operations, such as Long-Term Refinancing Operations (LTROs).

Table II
Balance Sheet of CD Issuers

Panel A provides descriptive statistics on the distribution of balance sheet characteristics of CD issuers. Means and quantiles are as of end-December and are computed from the pooled sample over the period 2008 to 2014. The number of issuer-year observations used to compute these moments is provided in the last column. Panel B relates CD outstanding amounts as of the end of December of each year to other balance sheet characteristics, in the pooled sample. Statistics are conditional on the issuer having a nonzero amount of CDs outstanding. The calculation of CD/(CD + Repo) is also conditional on the issuer having a nonzero amount of repurchase agreements outstanding. All variables are defined in Table AI. Balance sheet data are from Bankscope.

Panel A: Balance Sheet Characteristics							
	10^{th}	25^{th}	Mean	Median	75^{th}	90^{th}	*N*. Obs.
Size (log Total assets)	20.834	22.077	23.503	23.338	24.708	26.669	1,452
Loans/Assets	0.270	0.485	0.634	0.699	0.820	0.882	1,448
Customer deposits/Assets	0.036	0.202	0.375	0.351	0.577	0.669	1,422
ROA (%)	−0.201	0.159	0.332	0.406	0.748	1.047	1,446
ROE (%)	−3.883	2.526	1.576	5.424	8.342	13.461	1,446
Net income/Assets	−0.002	0.002	0.003	0.004	0.007	0.010	1,446
Net interest margin/Assets	0.005	0.011	0.017	0.016	0.021	0.030	1,414
Impaired loans/Loans (%)	1.028	2.243	5.414	3.908	6.586	11.899	1,059
Impaired loans/Equity (%)	8.231	17.134	58.575	38.381	72.999	135.547	1,074
Equity/Assets	0.030	0.046	0.083	0.075	0.110	0.136	1,452
Tier 1 capital (%)	7.600	9.230	13.074	11.200	14.300	18.250	458
Total regulatory capital (%)	9.900	11.600	16.124	13.705	16.910	21.400	486
Panel B: Size of CD Funding in Balance Sheets							
CD/Equity	0.008	0.053	1.176	0.215	0.693	2.246	971
CD/(CD + Repo)	0.010	0.053	0.340	0.229	0.611	0.855	218
CD/Total liabilities	0.003	0.010	0.095	0.035	0.091	0.222	1,007

main segment of the wholesale funding market in Europe. In Panel B, we further see that the aggregate volume of CDs outstanding is roughly twice as large as all funding provided by the ECB to European banks through its MROs. We do not find evidence that other sources of long-term funding by the ECB, such as LTROs, are a substitute for CD funding. We also find no evidence that aggregate CD volume drops around the two main LTROs. Finally, in Panel C we see that the CD market is also much larger than the unsecured interbank market.

Panel B of Table II provides descriptive statistics on the importance of CD funding in banks' balance sheets. For the median bank, CD funding represents 3.5% of total liabilities and 21.5% of equity. Reliance on CD funding can be much larger, and represents 9% of total liabilities and 69% of equity at the 75th percentile.

E. Pricing

Data on individual CD rates are not available—the Banque de France keeps them confidential—but we have daily data on average CD rates by rating-maturity buckets. Data are volume weighted and based on yields at

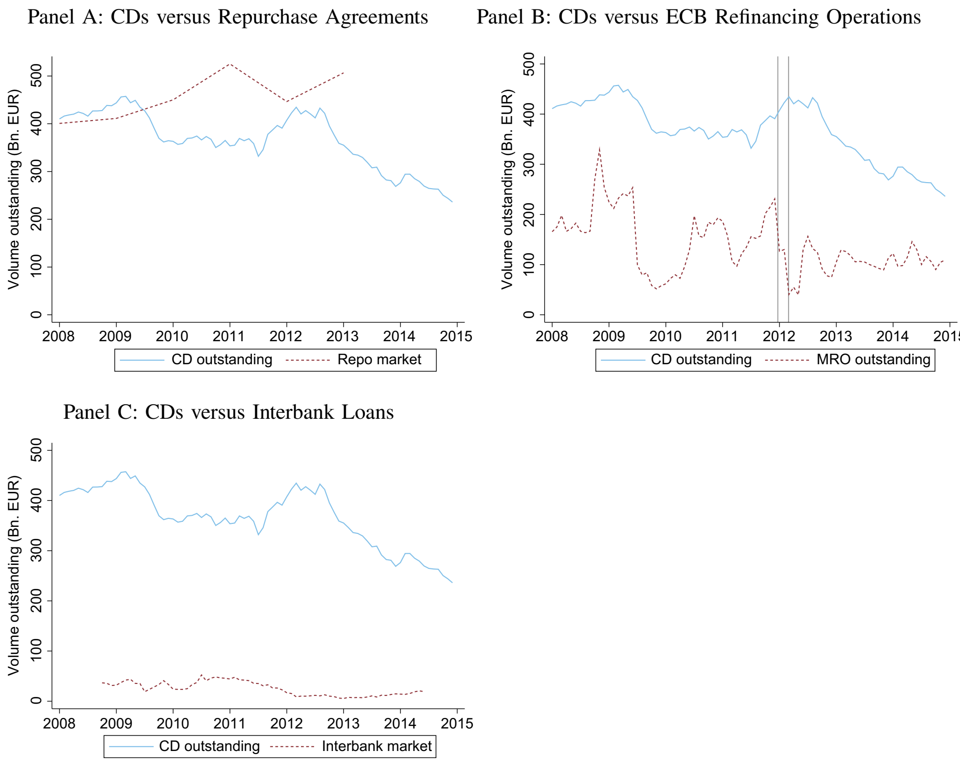

Figure 2. Size of the CD market relative to other wholesale funding markets. This figure compares the amount of euro-denominated CDs outstanding with three other segments of European wholesale funding markets. Panel A compares CDs with private repurchase agreements (CCP-based + bilateral + triparty). Data on the European repo market are provided by Mancini, Ranaldo, and Wrampelmeyer (2015) for the 2008 to 2013 period. The repo data involve partial double-counting. Panel B compares CDs with the outstanding amount of euro-denominated funding provided by the ECB to European banks through its Main Refinancing Operations (MROs). MROs have a maturity of one week and are provided in the form of repurchase agreements against eligible assets. The vertical lines correspond to the two main Long-Term Refinancing Operations (LTROs) on December 21, 2011, and February 29, 2012. LTROs are three-year refinancing operations. Data on MROs and LTROs come from the European Central Bank. Panel C compares CDs with overnight interbank loans. Data on the European interbank market are provided by de Andoain et al. (2016). For repo and interbank loan data, we proxy for the amount outstanding with daily turnover, because most contracts on these markets are overnight. All time series are monthly averages, except the repo data, which are at an annual frequency. (Color figure can be viewed at wileyonlinelibrary.com)

primary issuance. An important characteristic of CD funding is that it is cheaper than its close substitutes for borrowers with high creditworthiness.

In Figure 3, we compare the CD rate against interest rates on other unsecured sources of funds, at comparable maturities. The CD yield data are for borrowers in the highest rating bucket (short-term ratings F1+ by Fitch, A-1 by S&P). As can be seen in Panel A, CD rates are consistently lower

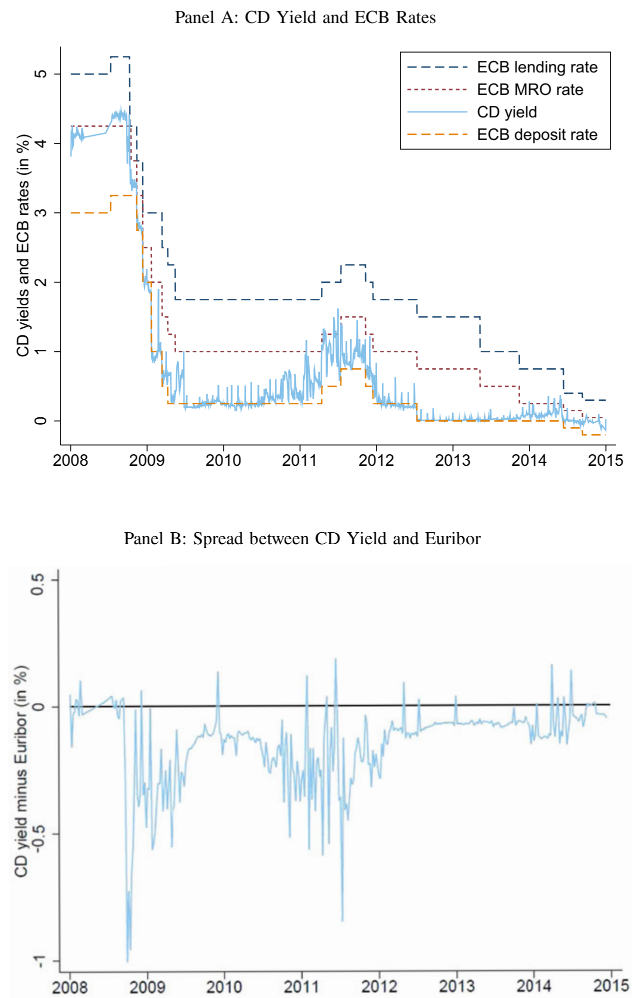

Figure 3. Short-term interest rates. Panel A displays the volume-weighted average yield on CDs issued by banks in the highest short-term rating bucket, from January 2008 to December 2014. The rate is for CDs with an initial maturity up to seven days. The figure also shows the three policy rates set by the ECB. The ECB rate for its Main Refinancing Operations (MROs) is in red. The deposit facility rate and the lending facility rate are in orange (bottom) and blue (top), respectively. Panel B plots the difference between the one-week CD yield and the one-week Euribor (rate for unsecured interbank lending in euros). Data source: European Central Bank. (Color figure can be viewed at wileyonlinelibrary.com)

than the ECB MRO rate, even though CD issuers do not have to post collateral. Perhaps more surprisingly, Panel B indicates that the spread between CD rates and the Euribor with similar maturity is negative. On average, CD rates are 15 basis points lower than the equivalent interbank rate. There are two possible reasons for this. First, while banks can invest excess reserves outside the interbank market, the largest CD market investors—money market funds—are restricted to invest in CDs or commercial paper. A second potential explanation is that the CD market is populated by borrowers of higher quality on average. Our empirical evidence is consistent with this view: banks whose quality drops are excluded from the market.

III. Market Freezes versus Bank-Specific Dry-Ups

In this section, we present our first main result: there was no market freeze in the European CD market over the 2008 to 2014 period. We then define and describe the events that we refer to as bank-specific wholesale funding dry-ups.

A. The Absence of a Market Freeze

A market freeze on wholesale funding would translate into a large and sudden drop in issuances in the CD market. We see in Figure 1 that such a drop did not happen over our sample period. The aggregate volume of CDs outstanding remained around EUR 400 Bn until mid-2012. This fact is remarkable because our sample period covers two periods of extreme banking stress (the subprime and European sovereign debt crises) and CDs are unsecured, which implies that CD funding should be more vulnerable to freezes than collateralized lending.

The sample period also contains two episodes of a relative decline in volume, but none of them is a freeze. The first is a EUR 100 Bn contraction in outstanding volume in 2009. However, this does not correspond to a period of stress for banks. To show this, in Figure 1 we superimpose the five-year EU Banks Credit Default Swap Index onto aggregate CD volume. The drop in volume in 2009 corresponds to a period in which spreads on European banks were actually falling. The second drop in CD issuances takes place after July 2012. This decline is not a freeze but rather a reflection of the fact that the CD market lost attractiveness as soon as the ECB lowered its deposit facility rate to 0%.[9] Furthermore, the progressive implementation of the Liquidity Coverage Ratio (LCR) for banks penalized short-term debt issuances.

Another sign of the aggregate resilience of the CD market is the stability of CD yields and their average maturity during periods of stress. Indeed, average yields remained below the ECB refinancing rate (see Figure 3, Panel A). Furthermore, there was no system-wide reduction in the average maturity of new CD issues when bank credit default swap spreads increased (see Internet Appendix Figure IA2).

[9] Di Maggio and Kacperczyk (2017) find that money market funds were more likely to exit the U.S. market after the introduction of the zero-interest-rate policy by the Fed.

B. The Identification of Bank-Specific Dry-Ups

While we do not observe a freeze in the CD market, we do observe a number of individual banks losing their CD funding. We call these events wholesale funding dry-ups. A *full dry-up* is said to occur when an issuer loses all of its CD funding, that is, its amount of CDs outstanding falls to zero. A *partial dry-up* is said to occur when an issuer loses 50% or more of its CD funding over a 50-day period. This 50% threshold is higher than what is typically considered in the literature; for instance, Covitz, Liang, and Suarez (2013), Oliveira, Schiozer, and Barros (2015), and Ippolito et al. (2016) use thresholds between 10% and 20%. Our main results are robust to alternative definitions of dry-ups based on a higher threshold (80%) or a shorter time window (30 days).

We proceed with caution when identifying dry-ups. First, we exclude infrequent borrowers to avoid incorrectly classifying the termination of their CDs as dry-ups. We only include issuers with an outstanding amount greater than EUR 100 million. We also ensure that all banks included in our sample issue CDs at least once a week over the six-month period preceding the dry-up. Second, we check whether the absence of new issues is caused by mergers or acquisitions, which would force issuers to become inactive.

Dry-ups are unlikely to capture a bank deliberately shifting to cheaper sources of funds, which we do not observe with the same granularity. First, as shown in Section E, CDs are cheaper than close substitutes (both interbank debt and ECB funding) over the full sample period for banks in the highest rating bucket. Relatedly, if an alternative source of funding were becoming more attractive than CDs, it would arguably be so for all issuers with a high rating, which is inconsistent with the fact that the occurrence of dry-ups is spread over the entire sample period. Furthermore, as we show below, dry-ups tend to affect banks with higher leverage, worse profitability, and lower ratings. Finally, we do not observe a clustering of dry-ups around the implementation of exceptional funding facilities by the ECB, such as LTROs, which are arguably targeted toward low-performing banks. We list all dry-ups in Internet Appendix Table IAI and check that they are not concentrated around LTRO allotment dates (December 21, 2011, and February 29, 2012) or around the launch of other lending facilities. To conclude, it is unlikely that substitution to cheaper funding instruments is driving dry-ups. If there is substitution, it has to be toward *more expensive* sources of funds.

Panel A of Table III displays the number of dry-ups, broken down by year and country. We identify 75 dry-ups, 29 of which are full. The year with the largest number of partial and full dry-ups is 2011. This marks the height of the European sovereign debt crisis and it is also the year when U.S. money market funds cut dollar funding to European banks (Ivashina, Scharfstein, and Stein (2015)). However, we do not see any contraction in aggregate issuances during this year, which suggests that investors reallocated their CD purchases to other banks. Over the sample period, the countries facing the highest number of full dry-ups are Ireland, Italy, and the United Kingdom.

Table III

Number and Magnitude of Dry-Ups

This table provides descriptive statistics on wholesale funding dry-ups. Panel A gives the total number of dry-ups, broken down by year, type, and home country of the bank. Panel B provides descriptive statistics on the magnitude of dry-ups, both in absolute terms and relative to the bank's equity as of end-December the preceding year. The magnitude of the dry-up is defined as the euro amount of the difference between the volume outstanding on the day a dry-up is identified and that 50 days before the dry-up. Both partial and full dry-ups are defined in Section B. Panel C provides evidence on the substitution between CDs and other sources of funds following dry-ups. It compares banks' funding sources as of end-December of year t between banks that face a full dry-up during year t and banks that do not. All reported statistics are differences in means and medians for banks that face a full dry-up during year t, relative to banks that do not face a full dry-up. All coefficients are computed after differencing out year fixed effects. The equality of means is tested based on a two-sample t-test. The equality of medians is tested using the Wilcoxon-Mann-Whitney test. Variables are defined in Table AI. p-values are in square brackets. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Panel A: Number of Dry-Ups

	Partial and Full Dry-Ups		Full Dry-Ups Only	
	Number of Dry-Ups	% Total	Number of Dry-Ups	% Total
2008	4	5.33	2	6.90
2009	6	8.00	3	10.34
2010	11	14.67	6	20.69
2011	18	24.00	8	27.59
2012	13	17.33	3	10.34
2013	13	17.33	3	10.34
2014	10	13.33	4	13.79
Total	75	100	29	100
By Country:				
Austria	2	2.66	2	6.89
Denmark	3	4.00	0	0.00
France	29	38.66	0	0.00
Germany	3	4.00	3	10.34
Ireland	7	9.33	7	24.14
Italy	8	10.66	5	17.24
Netherlands	3	4.00	2	6.89
Sweden	2	2.66	0	0.00
United Kingdom	8	10.66	5	17.24
Other	10	13.33	5	17.24

Panel B: Magnitude of Dry-Ups

	Min.	10th	25th	Mean	Median	75th	90th	Max.
Partial and Full Dry-Ups:								
Magnitude (EUR Mn)	63	136	228	967	512	1,260	3,258	5,289
Δ CD/Equity	0.001	0.008	0.016	0.233	0.068	0.174	0.491	5.293
Full Dry-Ups Only:								
Magnitude (EUR Mn)	103	152	216	847	403	1,004	2,240	4,182
Δ CD/Equity	0.051	0.054	0.089	0.639	0.259	0.517	2.250	5.293

(*Continued*)

Table III—*Continued*

Panel C: Funding Substitution after Dry-Ups				
	One Year after Dry-Up			
	Diff. from Mean		Diff. from Median	
Loans from central bank and other banks/Assets	0.082***	[0.000]	0.057***	[0.000]
Repurchase agreements/Assets	0.039**	[0.023]	0.026	[0.301]

To illustrate the events of interest, in Figure 4 we provide four examples, two of full dry-ups and two of partial dry-ups. The full dry-ups are those on Banca Monte dei Paschi (BMPS) and Allied Irish Banks (AIB). BMPS (dry-up in November 2012) had been facing large acquisition-related write-downs and had large exposure to Italian government debt. Hidden derivative contracts were made public toward the end of November 2012, causing a large loss. AIB (dry-up in June 2010) was severely affected by the global financial crisis and the collapse of the Irish real-estate market. In 2010Q4, the Irish government injected capital into the bank and became majority shareholder. Partial dry-ups on Unicredit and Dexia also occurred when these institutions publicly revealed major losses. Unicredit had to make write-downs on acquisitions and had large exposure to Greek sovereign debt. Dexia was greatly exposed to the U.S. subprime market through its U.S. monoline subsidiary. To further ensure that the dry-up events that we identify are associated with episodes of stress, for each such event we use Factiva to collect newspaper articles dated from the weeks surrounding the event. For 27 out of 29 full dry-ups, we find excerpts suggesting concerns about counterparty risk (see Internet Appendix Table IAI).

To analyze the magnitude of dry-ups and their dynamics, we measure the difference in CD amount outstanding before a dry-up starts until it ends.[10] Panel B of Table III shows that there is large heterogeneity in size. On average, the magnitude of a drop in CD funding is close to EUR 1 Bn, which represents more than 23% of bank equity. For a subset of institutions that rely heavily on CD funding, the amount of funding lost during the dry-up is larger than their equity. Thus, these are large funding shocks.

To get an aggregate view on dry-ups, we compute a monthly *Stress Index* according to

$$Stress\ Index_t = \frac{\sum_i D_{i,t}}{CD_{m,t}}, \tag{1}$$

where $D_{i,t}$ is the euro amount of the dry-up faced by issuer i in month t (conditional on i facing a dry-up; $D_{i,t} = 0$ otherwise) and $CD_{m,t}$ is the aggregate size of the CD market at the beginning of month t. Both partial and full dry-ups are included in the computation of the index. A high value of the index indicates

[10] For full dry-ups, the magnitude is equal to the outstanding amount 50 days before it falls to zero. For partial dry-ups, the magnitude is equal to the difference between the outstanding amount 50 days before the dry-up and the post-dry-up amount.

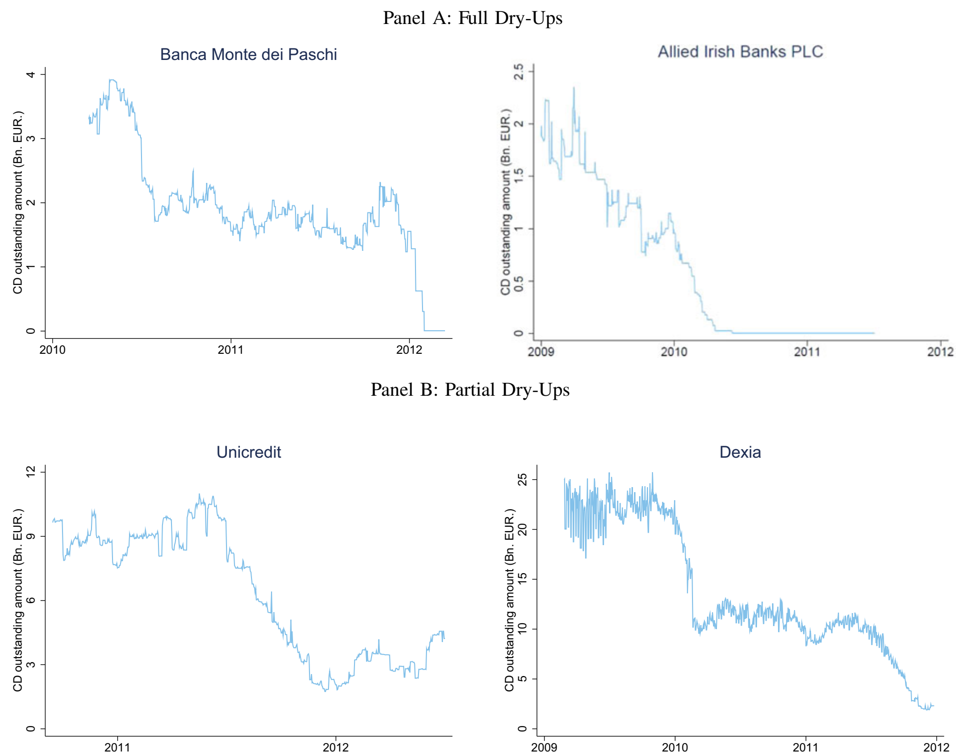

Figure 4. Complete and partial dry-ups. This figure gives four examples of full and partial dry-ups. It plots the amount of CDs outstanding for four selected European banks, at a daily frequency. Panel A provides two examples of full dry-ups (Banca Monte dei Paschi and Allied Irish Banks), that is, the amount of CDs outstanding after the dry-up falls to zero. Panel B provides two examples of partial dry-ups (Unicredit and Dexia), that is, the amount of CDs outstanding falls by 50% or more over 50-day period. (Color figure can be viewed at wileyonlinelibrary.com)

that a subset of issuers lose large amounts of funds in a given month. Internet Appendix Figure IA3 plots *Stress Index* over the sample period. It was high in 2008 and also spiked a number of times during the European sovereign debt crisis of 2011 to 2012. In our regressions, we use this index as a measure of stress in the CD market.

In the sample, banks facing dry-ups do not subsequently fail, and substitute CD funding with funding from the ECB and the repo market. Following a dry-up, we find that total borrowing from the central bank and other commercial banks, normalized by total assets, is on average 8% higher for banks facing a dry-up than for banks not facing a dry-up (see Panel C of Table III). Since unsecured interbank funding is small relative to ECB funding (see Figure 2), this substitution is driven mainly by the central bank. Similarly, reliance on repo funding is larger for banks facing a dry-up after this event occurs, but the increase is not statistically significant for the median. The fact that banks losing access to unsecured markets turn primarily to the central bank is consistent with more detailed evidence by Drechsler et al. (2016).

C. Observable Bank Characteristics before Dry-Ups

To describe dry-ups, we document ex ante observable characteristics associated with them. We compare the mean and median values of balance sheet and market characteristics for banks that face a full dry-up and banks that do not, both one year and two years before each dry-up. Specifically, we compute statistics in the pooled sample, after differencing out year fixed effects for each bank characteristic, to control for time trends. The equality of means is tested using a two-sample t-test and that of medians using the Wilcoxon-Mann-Whitney test. Results are displayed in Table IV.

Banks facing dry-ups tend to be weaker on average. Major differences exist in terms of profitability, asset quality, capitalization, and credit risk. Banks close to a dry-up have a lower ROA at the end of the previous year, indicating that they use their funds less efficiently. The same lower profitability is reflected in a lower net income before the drop in CD funding. One year before the dry-up, these differences are statistically significant at the 1% level in all but one case. In some cases, they are also significant two years before. The fact that the profitability of banks that will face a dry-up is lower arises in part from their asset quality being lower, as measured by their ratio of impaired loans to equity. These institutions have higher credit risk, as evidenced by a higher credit default swap spread the year before the drop in CD funding and by a significantly lower credit rating up to two years before the drop. Finally, banks that are about to experience a dry-up have lower reliance on CD funding, as measured by the share of total debt.

Finally, institutions that will experience a drop in CD funding also have a significantly lower ratio of book equity to total assets up to two years before the drop. However, the fact that they are significantly less capitalized, with an average book equity ratio that is 3.6 percentage points lower, is not reflected by differences in regulatory capital. Measures of regulatory capital poorly predict the occurrence of dry-ups. This is consistent with Acharya, Engle, and Pierret (2014), who find no correlation between regulatory capital and perceived bank risk. Furthermore, banks close to a dry-up have a more negative stock return over the past year.

Overall, these results suggest that dry-ups do not occur as sunspots, as would be the case if they were pure coordination failures among lenders (Diamond and Dybvig (1983)). Instead, the fact that dry-ups correlate with worse publicly observable fundamentals is consistent with the idea that CDs have to become information-sensitive before dry-ups occur.

IV. Informational Content of Funding Dry-Ups

We test whether funding dry-ups affect high- and low-quality banks equally. We measure quality that is not observable by the market at the time of dry-ups

Table IV

Balance Sheet and Market Characteristics before Full Dry-Ups

This table compares balance sheet and market characteristics at the end of years $t-1$ and $t-2$ between banks that face a full dry-up during year t and banks that do not face a full dry-up. All reported statistics are differences in means and medians for banks that face a full dry-up during year t, relative to banks that do not face a full dry-up. All coefficients are computed after differencing out year fixed effects, to control for time trends common to both groups. "Stock return" refers to the return over the past calendar year. The equality of means is tested based on a two-sample t-test. The equality of medians is tested using the Wilcoxon-Mann-Whitney test. Variables are defined in Table AI. p-values are in square brackets. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

	One Year before Dry-Up		Two Years before Dry-Up		
	Diff. from Mean	Diff. from Median	Diff. from Mean	Diff. from Median	*N*. Obs
CD Borrowing:					
CD/Total debt	−0.059***	−0.026***	−0.053**	−0.025***	1,032
	[0.007]	[0.000]	[0.016]	[0.001]	
Loans and Deposits:					
Loans/Assets	−0.015	−0.065	0.019	0.009	1,119
	[0.744]	[0.472]	[0.686]	[0.745]	
Deposits/assets	0.021	0.022	0.052	0.129	1,105
	[0.653]	[0.618]	[0.268]	[0.259]	
Profitability:					
ROA	−1.253***	−0.582***	−0.271	−0.150**	1,120
	[0.000]	[0.000]	[0.230]	[0.018]	
Net income/Assets	−0.015***	−0.007***	−0.003	−0.002**	1,120
	[0.000]	[0.000]	[0.301]	[0.018]	
Asset Quality:					
Impaired loans/Total loans	1.827	1.325	0.064	0.485	825
	[0.206]	[0.259]	[0.962]	[0.574]	
Impaired loans/Equity	55.879***	52.790***	22.362	11.234*	836
	[0.001]	[0.006]	[0.174]	[0.054]	
Credit Risk:					
CDS spread	82.180	110.245**	0.041	10.584	516
	[0.249]	[0.014]	[0.999]	[0.402]	
Short-term credit rating	−0.424***	−0.474**	−0.320**	−0.118	977
	[0.005]	[0.011]	[0.036]	[0.179]	
Capitalization:					
Equity/Assets	−0.037***	−0.033***	−0.032**	−0.024***	1,122
	[0.007]	[0.000]	[0.015]	[0.000]	
Regulatory cap./RWA	8.166*	−0.453	8.354*	0.331	404
	[0.088]	[0.910]	[0.072]	[0.216]	
Stock return	−0.360***	−0.315***	−0.219*	−0.168	273
	[0.001]	[0.001]	[0.064]	[0.400]	

using future performance conditional on public information. Theories based on adverse selection predict a positive relation between funding dry-ups and bank quality. In contrast, we find a negative relation, which points toward the existence of informed lenders.

A. Funding Dry-Ups Predict Lower Future Bank Quality

In this section, we show that funding dry-ups predict lower future bank quality. We start by using balance sheet data only, and then extend the analysis to market data. For each drop in CD funding occurring during year t, only the balance sheet characteristics at the end of year $t-1$ are observable. We test whether the occurrence of dry-ups predicts the change in relevant balance sheet characteristics between dates $t-1$ and t, after including as controls standard predictors of such bank outcomes. We focus on year-to-year changes in balance sheet characteristics because variables in levels are likely to be autocorrelated.[11] We estimate

$$\Delta Y_{i,t} = \beta_0 DryUp_{i,t} + \beta_1 Size_{i,t-1} + \beta_2 Controls_{i,t-1} + \beta_3 Controls_{c,t-1} + FE_c + FE_t + \varepsilon_{i,t}, \tag{2}$$

where $DryUp_{i,t} = \mathbb{1}\{t-1 \leq \tau_{DryUp_i} < t\}$ is an indicator function that takes a value of one when a dry-up affects issuer i between the end of year $t-1$ and the end of year t, $\Delta Y_{i,t} = Y_{i,t} - Y_{i,t-1}$ is the change in a given balance sheet characteristic between the end of year $t-1$ (observable) and the end of year t (unobservable at the time of the dry-up), and FE_c and FE_t are country and year fixed effects. We estimate regression coefficients separately for full and partial dry-ups. We use the change in ROA as our main dependent variable. Our coefficient of interest, β_0, is positive and significant if adverse selection is driving our results (i.e., better performing banks withdraw from the market).

Regression coefficients are presented in Table V. Panel A corresponds to all dry-ups and Panel B to full dry-ups only. As seen in our main specifications (columns (1) and (2)), the occurrence of a drop in CD funding during year t is associated with a decrease in ROA between the end of year $t-1$ and the end of year t. This result is true for all types of dry-ups, at statistically significant levels, and is robust to the inclusion of several bank-level controls (size, ROA, impaired loans over total loans at $t-1$, book equity over total assets, and short-term credit rating) and country-level controls (sovereign CDS spread).[12] Our empirical evidence suggests that dry-ups contain information about future bank quality. These estimates have a cross-sectional interpretation: in the cross-section, banks facing a dry-up are more likely to have lower future performance.

This baseline result can be extended along three dimensions. First, it is robust to the inclusion of bank fixed effects, as seen in column (3). Therefore, over time, a given bank faces a dry-up before large decreases in ROA. Second, we provide evidence of the informational content of dry-ups at longer term

[11] This regression specification is in the spirit of Bertrand, Schoar, and Thesmar (2007). In their paper, future changes in ROA of bank-dependent firms are regressed on banks' lending policy.

[12] In unreported regressions, we check that our estimates are robust to dropping the impaired loans variable, which shrinks the sample size. The results are also robust to using a constant sample size.

Table V

Dry-Ups Forecast Future Changes in ROA

In this table, we estimate equation (2) with changes in ROA as the dependent variable. Panel A includes both partial and full dry-ups. Panel B focuses on full dry-ups only. Changes in ROA are between the end of year $t-1$ (observable at the time of the dry-up) and the end of year t (unobservable at the time of the dry-up). *DryUp* is a dummy variable that takes a value of one for bank i if it faces a dry-up between $t-1$ and t. Time and country fixed effects are included. In column (3), we include bank fixed effects. In column (4), we add excess stock returns in the previous year as an additional control variable. In column (5), we interact the *DryUp* dummy with two dummy variables that equal one if a bank's share of CD funding to total liabilities is between 4% and 9% or is above 9%, respectively. In column (6), we interact the *DryUp* dummy with a *Crisis* dummy that equals one in 2011 and 2012. Control variables include size, ROA, impaired loans over total loans at $t-1$, book equity over total assets, bank short-term credit rating, and sovereign CDS spread. Variables are defined in Table AI. Standard errors, clustered at the bank level, are in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Dependent Variable: $\Delta ROA = ROA_t - ROA_{t-1}$						
	Baseline				Share CD	Crisis
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Partial and Full Dry-Ups						
DryUp	−0.395**	−1.681***	−0.392*	−1.002**	−0.878***	−0.679***
	(0.142)	(0.427)	(0.121)	(0.577)	(0.295)	(0.206)
DryUp * Share CD $\in [4\%, 9\%]$					0.331	
					(0.357)	
DryUp * Share CD $> 9\%$					0.367	
					(0.423)	
DryUp * Crisis						0.101
						(0.192)
Controls	No	Yes	Yes	Yes	Yes	Yes
Returns control	No	No	No	Yes	No	No
Issuer fixed effect	No	No	Yes	No	No	No
Adj. R^2	0.013	0.351	0.682	0.378	0.366	0.368
N. Obs.	948	496	496	231	496	496
Panel B: Full Dry-Ups Only						
DryUp	−0.341***	−1.086***	−0.782***	−0.987***	−0.834***	−0.843***
	(0.135)	(0.222)	(0.232)	(0.257)	(0.255)	(0.258)
DryUp * Share CD $\in [4\%, 9\%]$					0.456	
					(0.504)	
DryUp * Share CD $> 9\%$					0.431	
					(0.554)	
DryUp * Crisis						0.321
						(0.551)
Controls	No	Yes	Yes	Yes	Yes	Yes
Returns control	No	No	No	Yes	No	No
Issuer fixed effect	No	No	Yes	No	No	No
Adj. R^2	−0.001	0.362	0.691	0.389	0.365	0.369
N. Obs.	948	496	496	231	496	496

horizons. We reestimate equation (2) with $Y_{i,t+1} - Y_{i,t-1}$ as the dependent variable, that is, we consider whether dry-ups predict future changes in ROA over a two-year period starting at the end of December in the year preceding a dry-up. The estimates, reported in Internet Appendix Table IAII, show that dry-ups predict a longer-term decrease in ROA.

Third, we show that the informational content of dry-ups does not disappear in times of high market stress. Indeed, if market stress corresponds to more acute information asymmetries between lenders and borrowers, lenders are expected to find it more difficult to distinguish between high- and low-quality borrowers (Heider, Hoerova, and Holthausen (2015)). If this is the case, dry-ups may not be informative during crises. In Tables V and VI, we reestimate equation (2) after including an interaction term between the *DryUp* dummy and a *Crisis* dummy that equals one in 2011 and 2012. These years correspond to the height of the European sovereign debt crisis. As can be seen in Figure 1, they are also the years in which the credit default swap spread of European banks reached its highest level. If the predictive power of dry-ups declines or disappears in times of crisis, the estimated coefficient on this interaction term should have a sign that is opposite that on the *DryUp* dummy and significant. We do not find this in any of the specifications, which suggests that dry-ups contain information even when market stress is high.

B. Addressing Reverse Causality Concerns

While previous results cast doubt on the idea that adverse selection is driving funding dry-ups, they do not allow us to conclude that dry-ups are due to informed lenders. Indeed, a potential endogeneity concern when estimating equation (2) is reverse causality: drops in bank performance could be caused by a reduction in funding. This can occur if dry-ups are due to coordination failures among lenders, as in Diamond and Dybvig (1983) and Goldstein and Pauzner (2005), which may force asset fire sales or prevent banks from investing in valuable projects. If this were the case, a negative relation between dry-ups and future performance could arise even if dry-ups are ex ante random. We address this reverse causality concern in three ways. We then discuss why coordination failures are unlikely in our context.

First, we replace changes in ROA by changes in the ratio of impaired loans to total loans as the dependent variable when estimating equation (2). Changes in impaired loans arguably cannot be caused by funding shocks because they relate to a stock of preexisting loans, which have been extended before the dry-up. They are thus exogenous with respect to the occurrence of the drop in CD funding. Estimation results in Table VI are consistent with those obtained for changes in ROA. The occurrence of dry-ups predicts an increase in the ratio of impaired loans, at statistically significant levels, even after including bank- and country-level controls associated with loan performance. This result also extends at a two-year horizon, as seen in Internet Appendix Table IAII. Dry-ups predict a longer-term increase in the ratio of impaired loans, which is significant at the 1% level.

Table VI

Dry-Ups Forecast Future Changes in Asset Quality (Impaired Loans/Loans)

In this table, we estimate equation (2) with changes in the ratio of impaired loans to total loans as the dependent variable. Panel A includes both partial and full dry-ups. Panel B focuses on full dry-ups only. Changes in impaired loans are between the end of year $t-1$ (observable at the time of the dry-up) and the end of year t (unobservable at the time of the dry-up). *DryUp* is a dummy variable that takes a value of one for bank i if it faces a dry-up between $t-1$ and t. Time and country fixed effects are included. In column (3), we include bank fixed effects. In column (4), we add excess stock returns in the previous year as an additional control variable. In column (5), we interact the *DryUp* dummy with two dummy variables that equal one if a bank's share of CD funding to total liabilities is between 4% and 9% or is above 9%, respectively. In column (6), we interact the *DryUp* dummy with a *Crisis* dummy that equals one in 2011 and 2012. Control variables include size, ROA, impaired loans over total loans at $t-1$, book equity over total assets, bank short-term credit rating, and sovereign CDS spread. Variables are defined in Table AI. Standard errors, clustered at the bank level, are in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Dependent Variable: Δ Impaired Loans/Loans						
	Baseline				Share CD	Crisis
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Partial and Full Dry-Ups						
DryUp	0.582***	0.749***	0.385**	0.512***	0.621***	0.596***
	(0.140)	(0.207)	(0.163)	(0.199)	(0.178)	(0.164)
DryUp * Share CD ∈ [4%, 9%]					−0.320	
					(0.385)	
DryUp * Share CD > 9%					−0.214	
					(0.306)	
DryUp * Crisis						−0.049
						(0.098)
Controls	No	Yes	Yes	Yes	Yes	Yes
Returns control	No	No	No	Yes	No	No
Issuer fixed effect	No	No	Yes	No	No	No
Adj. R^2	0.100	0.109	0.529	0.111	0.113	0.115
N. Obs.	676	490	490	229	490	490
Panel B: Full Dry-Ups Only						
DryUp	1.773***	3.045***	1.345***	2.157***	1.197***	1.076***
	(0.274)	(0.375)	(0.292)	(0.303)	(0.282)	(0.253)
DryUp * Share CD ∈ [4%, 9%]					−0.467	
					(1.047)	
DryUp * Share CD > 9%					−0.453	
					(0.958)	
DryUp * Crisis						−0.087
						(0.157)
Controls	No	Yes	Yes	Yes	Yes	Yes
Returns control	No	No	No	Yes	No	No
Issuer fixed effect	No	No	Yes	No	No	No
Adj. R^2	0.132	0.141	0.558	0.152	0.156	0.159
N. Obs.	676	490	490	229	490	490

Second, if funding shocks were actually causing performance drops, this effect should be particularly severe for banks that depend a lot on CDs. Accordingly, we interact the *DryUp* dummy variable with another dummy variable equal to one if the share of a bank's CD financing over total liabilities is in the third or fourth quartiles of the distribution. If endogeneity concerns are important, these interaction terms should be statistically significant, with the same sign as β_0, and increasing in magnitude. Estimation results are reported in column (5) of Tables V (for ROA) and VI (for impaired loans). In all cases, the estimated interaction terms are not statistically significant, indicating that the estimate for our coefficient of interest is not driven by a subset of banks with large exposure to the CD market. Dry-ups are also predictive of future profitability and asset quality even for banks with little CD funding. This result, which extends to a two-year horizon as seen in Internet Appendix Table IAII, casts serious doubt on the idea that endogeneity concerns are severe in our context. Rather, it is consistent with lenders cutting funding based on information about future fundamentals, as the share of CD funding over total liabilities should not matter in this case.

Third, we show that dry-ups do not force banks to downsize significantly. In Table VII, we reestimate equation (2) with changes in size (Panel A) and changes in loans to total assets (Panel B) as the dependent variable. The coefficients on the dummy variable capturing the occurrence of dry-ups are never statistically significant. They are also insignificant for banks that rely heavily on CD funding. The fact that banks facing dry-ups do not engage in costly fire sales is likely due to the substitution of CD funding by central bank funding (see Section B). This result suggests that the reduction in ROA is not due to fire sales, which mitigates reverse causality concerns.

Finally, we stress that dry-ups arising from coordination failures are unlikely in our context. A necessary condition for coordination failures to arise is that strategic complementarities among lenders are present: the decision of a given lender to withdraw funding should depend on other lenders' decisions to maintain or withdraw funding. Such strategic complementarities can exist only if cutting funding can induce the borrowing bank to default. Instead, we do not find that dry-ups induce banks to default (since we observe their balance sheet after dry-ups), or even to downsize significantly. Moreover, if strategic complementarities were present, they should be stronger for banks that rely more on CD funding. Indeed, a funding shock is more likely to induce such banks to default or liquidate assets. Our finding that the predictive power of dry-ups on future performance is equally strong even for banks relying on CDs to a small extent (column (3) of Tables V and VI) further suggests that coordination failures are unlikely to explain dry-ups.

Taken together, all of the results in this section suggest that the observed funding dry-ups are driven by at least some informed lenders monitoring and cutting funding to low-quality banks. Below, we show that the results point to the coexistence of such informed lenders with uninformed lenders.

Table VII
Dry-Ups Do Not Forecast Future Changes in Size or Loans to Total Assets

In this table, we estimate equation (2) with changes in bank size (Panel A) and in loans to total assets (Panel B) as the dependent variable. Bank size is defined as the logarithm of total assets. Changes in both size and loans are between the end of year $t-1$ (observable at the time of the dry-up) and the end of year t (unobservable at the time of the dry-up). *DryUp* is a dummy variable that takes a value of one for bank i if it faces a partial or a full dry-up between $t-1$ and t. Time and country fixed effects are included. In column (3), we include bank fixed effects. In column (4), we add excess stock returns in the previous year as an additional control variable. In column (5), we interact the *DryUp* dummy with two dummy variables that equal one if a bank's share of CD funding to total liabilities is between 4% and 9% or is above 9%, respectively. In column (6), we interact the *DryUp* dummy with a *Crisis* dummy that equals one in 2011 and 2012. Control variables include size, ROA, impaired loans over total loans at $t-1$, book equity over total assets, bank short-term credit rating, and sovereign CDS spread. Variables are defined in Table AI. Standard errors, clustered at the bank level, are in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

	Baseline				Share CD	Crisis
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Δ Size						
DryUp	−0.039	−0.019	−0.021	−0.015	−0.009	−0.015
	(0.036)	(0.020)	(0.024)	(0.022)	(0.018)	(0.017)
DryUp * Share CD ∈ [4%, 9%]					−0.009	
					(0.032)	
DryUp * Share CD > 9%					−0.016	
					(0.030)	
DryUp * Crisis						−0.008
						(0.009)
Controls	No	Yes	Yes	Yes	Yes	Yes
Returns control	No	No	No	Yes	No	No
Issuer fixed effect	No	No	Yes	No	No	No
Adj. R^2	0.031	0.197	0.274	0.222	0.196	0.201
N. Obs.	950	496	496	231	496	496
Panel B: Δ Loans/Assets						
DryUp	0.004	−0.001	0.008	0.003	0.002	0.007
	(0.007)	(0.010)	(0.014)	(0.013)	(0.009)	(0.014)
DryUp * Share CD ∈ [4%, 9%]					0.012	
					(0.023)	
DryUp * Share CD > 9%					0.014	
					(0.025)	
DryUp * Crisis						−0.002
						(0.015)
Controls	No	Yes	Yes	Yes	Yes	Yes
Returns control	No	No	No	Yes	No	No
Issuer fixed effect	No	No	Yes	No	No	No
Adj. R^2	0.016	0.034	0.119	0.055	0.054	0.055
N. Obs.	947	496	496	321	496	496

C. Market Returns around Dry-Ups

We provide evidence that dry-ups are triggered by the disclosure of new information by analyzing stock returns around dry-ups. First, if dry-ups are caused by the release of negative news, we expect this information to also be reflected in the stock market. Second, if dry-ups correspond to high-quality banks self-selecting out of the market, we expect positive abnormal returns to be realized when dry-ups occur. However, if dry-ups are caused by funding cuts from both informed and uninformed investors, abnormal returns could be zero. This would be the case if the negative news has already been priced because informed lenders also participate in the stock market. Third, unless there is massive segmentation between the CD and equity markets, we do not expect dry-ups to forecast long-term stock returns.

We perform an event study over the period of eight weeks preceding dry-ups. We define the beginning of the dry-up as the first day following the last CD issuance. In Panel A of Table VIII, we report weekly cumulative abnormal returns over the event window, and compute standard errors using the formulas in MacKinlay (1997). We find a negative cumulative abnormal return of 8% over the five weeks preceding dry-ups, which is statistically significant at the 1% level. This result gives further reassurance that dry-ups are initially driven by adverse fundamental information.

Next, we study excess stock returns during dry-ups. Since data on CD issues by banks are published by the Banque de France at a weekly frequency, the information that a dry-up occurred should quickly become public. Therefore, if dry-ups correspond to funding cuts by lenders to borrowers, information related to their occurrence should be priced. In Panel B, we compute the average cumulative abnormal return on the week of occurrence of dry-ups, which equals 0.006 and is statistically insignificant. When extending the window to a period covering one week before and one week after dry-ups, the cumulative abnormal return remains insignificant. These estimates are consistent with information about dry-ups being incorporated into prices and inconsistent with adverse selection.

Finally, if investors do not understand that dry-ups correspond to adverse selection by high-quality banks, dry-ups should be followed by positive excess returns. We reestimate equation (2) using future realized abnormal stock returns as the dependent variable. In Panel C of Table VIII, we report results for the six-month and one-year periods that follow the occurrence of a dry-up. We do not find any statistically significant relation between dry-ups and future abnormal stock returns at either horizon. Therefore, dry-ups are unlikely to be driven by adverse selection.

V. Heterogeneity between Informed and Uninformed Lenders

A potential interpretation of the results in the previous section is that all lenders are perfectly informed about the quality of borrowers, that is, there are no uninformed lenders. If so, lenders should price counterparty risk for each

Table VIII

Issuer Stock Returns around Dry-Ups

In this table, we study issuer stock returns around dry-ups. Panel A performs event studies before partial and full dry-ups. The week of the event is denoted τ and we focus on an event window of eight weeks preceding the event. We report cumulative abnormal returns over the entire event window. Abnormal returns are computed as $R_{it} - R_{mt}$, where R_{mt} is the equally weighted return computed for all sample banks. In Panel B, we compute cumulative excess stock returns for banks facing a dry-up the week of the event, and over a period that starts one week before the event and ends after the event. In Panel C, we focus on the period after the event. We estimate equation (2) using abnormal stock returns as the dependent variable. Regressions are estimated over two time horizons, respectively, six months and one year after the dry-up occurs. All regressions use quarterly data and include time and country fixed effects, and two specifications also include issuer fixed effects. Control variables include size, ROA, impaired loans over total loans at $t-1$, book equity over total assets, bank short-term credit rating, and sovereign CDS spread. Variables are defined in Table AI. Standard errors, clustered at the bank level, are in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Panel A: Abnormal Stock Returns before Dry-Ups

	Cumulative Abnormal Return	95% Confidence Interval	p-value
Week $\tau - 8$	−0.016	[−0.031, 0.005]	0.101
Week $\tau - 7$	−0.009	[−0.036, 0.017]	0.245
Week $\tau - 6$	−0.010	[−0.039, 0.017]	0.223
Week $\tau - 5$	−0.017*	[−0.042, 0.007]	0.081
Week $\tau - 4$	−0.032**	[−0.060, −0.004]	0.011
Week $\tau - 3$	−0.044***	[−0.074, −0.014]	0.003
Week $\tau - 2$	−0.071***	[−0.112, −0.029]	0.001
Week $\tau - 1$	−0.080***	[−0.130, −0.031]	0.001

Panel B: Abnormal Stock Returns during Dry-Ups

	Week τ	Weeks $\tau - 1$ to $\tau + 1$
DryUp	0.006	−0.015
	(0.017)	(0.020)

Panel C: Abnormal Stock Returns after Dry-Ups

	6 Months			1 Year		
DryUp	−0.091	−0.078	−0.081	−0.038	−0.093	−0.091
	(0.071)	(0.064)	(0.080)	(0.064)	(0.067)	(0.100)
Controls	No	Yes	Yes	No	Yes	Yes
Issuer fixed effect	No	No	Yes	No	No	Yes
Adj. R^2	0.151	0.319	0.228	0.151	0.698	0.678
N. Obs.	1,131	717	717	1,091	717	717

bank individually. If the requested interest rate is above the rate at which the ECB is lending, then borrowers turn to the central bank. In this case, dry-ups would be demand-driven and correspond to banks switching funding sources. In this section, we provide multiple pieces of evidence suggesting that such a mechanism is unlikely to explain the main patterns in the data. Rather, our

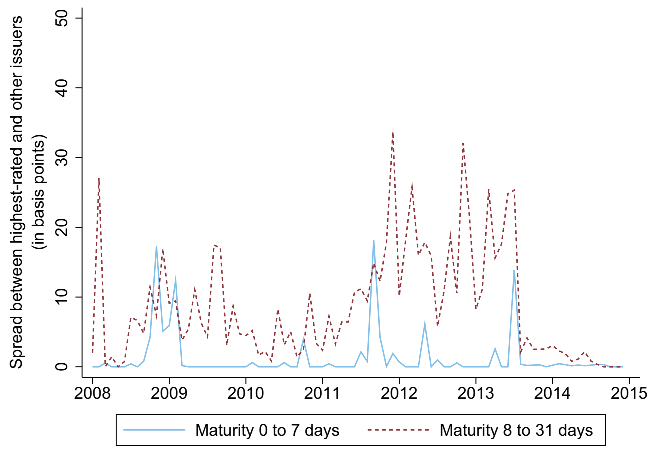

Figure 5. Price dispersion in the CD market. This figure plots the spread between the average rate paid by issuers with the highest credit ratings and the average rate paid by issuers with the lowest credit ratings. The spreads are computed as monthly averages and expressed in basis points. The highest credit rating is F1+ in the scale by Fitch Ratings. All spreads are weighted by the volume of new issues. The solid line corresponds to new CD issues with an initial maturity between zero and seven days, and the dotted line to new CD issues with an initial maturity between eight and 31 days. (Color figure can be viewed at wileyonlinelibrary.com)

findings are more consistent with models in which uninformed lenders coexist with informed lenders and purchase CDs as long as they remain information insensitive.

A. Interest Rate Dispersion

We start by studying the dispersion in interest rates in the CD market. If all lenders are informed, then CD rates should change with bank quality. Given that there is significant dispersion in measures of bank quality among our sample banks (see Table II), we should expect significant dispersion in interest rates. We do not directly observe individual CD rates, but we can compute the spread between the average rate paid by banks with the highest rating and the rate paid by lower rated banks. We do so for CDs with initial maturities between 0 and 7 and between 8 and 31 days. In Figure 5 we show that spreads remain remarkably low over our sample period. For CDs with maturities between zero and seven days (respectively, eight and 31 days), the spread is on average 1.3 (8.7) basis points over the entire sample period, and only rarely exceeds 10 (20) basis points. In contrast, the difference between CD yields and the main ECB rate is 51 basis points on average over the sample period (see Figure 3). Therefore, we conclude that price dispersion is extremely limited, even below the ECB rate. This feature of the data is most consistent with models in which some lenders are uninformed, and in which borrowers of different quality can access funding at similar rates as long as they are perceived as safe.

Next, we ask whether borrowing rates increase significantly in the months preceding dry-ups. If all lenders were informed, one would observe an increase in rates as borrowers are perceived as riskier—the CD market would continue to clear as long as the CD rate is below the cost of ECB borrowing. Our lack of bank-level data forces us to rely on aggregate time series. Specifically, we check whether spikes in the number and magnitude of dry-ups, as measured by *Stress Index* (see Section B), are preceded by increases in spreads between highly rated and low-rated banks. We regress *Stress Index* on contemporaneous and lagged values of this spread, at a weekly frequency. We run this regression both in levels and in first differences and report estimates in Internet Appendix Table IAIII. We are unable to find evidence that interest rates for low-rated issuers increase prior to dry-ups. For CDs with an initial maturity between 8 and 31 days, the relation in levels is even negative, but disappears when the model is estimated in first differences. We further confirm graphically, in Internet Appendix Figure IA4, that there is no positive relationship between the spread paid by low-rated issuers and stress in the CD market. Overall, these results further suggest that adjustments in the CD market occur primarily through quantities rather than prices, a feature that is most consistent with theories by Gorton and Pennacchi (1990) and Dang, Gorton, and Holmström (2012). Below, we provide further evidence that is consistent with these theories and hard to reconcile with either adverse selection or a model in which all lenders are fully informed.

B. Heterogeneity across Lenders and Maturity Shortening

In the presence of informed lenders, debt securities are valuable for uninformed lenders as long as they remain information-insensitive. However, for a given issuer, not all CDs become information-sensitive simultaneously. When fundamentals deteriorate, theory predicts that longer term CDs become information-sensitive before shorter term CDs, since they get repaid later (Holmström (2015)), in which case we should observe a shortening of the maturity of new issues prior to dry-ups. In contrast, the view that all investors are perfectly informed does not yield any specific prediction about maturity.

We provide evidence for this mechanism by investigating the dynamics of the maturity of new issues in the six months leading up to dry-ups. To do so, we estimate

$$Maturity_{i,t} = \sum_{j=1}^{6} \beta_j DryUp_{i,\tau-j} + FE_i + FE_t + \varepsilon_{i,t}, \tag{3}$$

where $Maturity_{i,t}$ is the volume-weighted average maturity of all new issues by bank i in month t, τ is the month in which institution i faces a dry-up, and $DryUp_{i,\tau-j}$ is a dummy variable that equals one for i if it faces a dry-up at date $t = \tau - j$. We estimate six of these dummy variables, for $j \in \{1, ..., 6\}$. The specification also includes bank fixed effects (FE_i), as we focus on within-issuer variation, and month fixed effects (FE_t), to difference out any time trend

Table IX

Maturity Shortening before Dry-Ups

The volume-weighted average maturity of new issues at a monthly frequency is regressed on issuer and time fixed effects and on a set of dummy variables (equation (3)). A dummy variable at date $\tau - j$ equals one if the bank faces a dry-up at date τ and zero otherwise, for $j \in \{1, ..., 6\}$, that is, up to six months before the dry-up. Column (1) includes partial and full dry-ups. Column (2) focuses on full dry-ups only. Standard errors, clustered at the bank level, are in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Dependent Variable: Weighted Average Maturity of New Issues		
	Partial and Full Dry-Ups (1)	Full Dry-Ups Only (2)
Month $\tau - 1$	−25.360***	−29.511***
	(2.285)	(4.513)
Month $\tau - 2$	−17.345***	−30.001***
	(3.914)	(5.998)
Month $\tau - 3$	−12.134***	−14.664***
	(1.699)	(4.742)
Month $\tau - 4$	−7.628	−11.610
	(4.902)	(7.368)
Month $\tau - 5$	−7.506*	−3.930
	(3.750)	(5.243)
Month $\tau - 6$	−0.689	15.504***
	(4.132)	(3.858)
Issuer fixed effect	Yes	Yes
Month fixed effect	Yes	Yes
Adj. R^2	0.166	0.165
N. Obs.	11,420	11,420

in maturity common to all issuers. Estimates are reported in Table IX, both for all types of dry-ups and for full dry-ups only.

The average maturity of new issues starts to shorten about five months before the dry-up takes place, with the shortening becoming statistically significant at the 1% level three months before the dry-up. This is true for both full and partial dry-ups. The effect is economically large, as the within-bank average maturity of new issues (after accounting for time trends) drops by about 30 days before full dry-ups and 25 days before partial dry-ups. The monotonic decline in average maturity suggests that creditors become increasingly reluctant to buy CDs at longer maturities. Such maturity shortening is consistent with longer term CDs turning information-sensitive before shorter term CDs, which gives rise to dry-ups.[13] This result is in line with Gorton, Metrick, and Xie (2015), who document maturity shortening for U.S. money market instruments before the failure of Lehman Brothers. As a general feature of events that we treat as dry-ups, maturity shortening is hard to reconcile with a demand-driven explanation, including explanations based on adverse selection.

[13] A related interpretation is that some creditors engage in costly monitoring and use maturity shortening to strengthen their discipline over the bank prior to the dry-up (Calomiris and Kahn (1991)).

C. Events Triggering Dry-Ups

If dry-ups occur when information-insensitive securities turn information-sensitive, public news is needed to trigger a change in beliefs by uninformed lenders (Dang, Gorton, and Holmström (2012)). As we already discuss, Internet Appendix Table IAI provides evidence of bad public news in the weeks surrounding dry-ups. Furthermore, we document that stock prices tend to fall prior to dry-ups. In this subsection, we show that rating downgrades play a significant role in triggering large changes in CD funding. We focus on downgrades because they are public and easily interpretable. Moreover, ratings are a key determinant of access to the money market for borrowers (see Crabbe and Post (1994)).

Specifically, we estimate

$$\log(CD_{i,t}) = \sum_{j=-5}^{5} \beta_j Downgrade_{i,\tau+j} + FE_i + FE_t + \varepsilon_{i,t}, \tag{4}$$

where $CD_{i,t}$ is the amount of CDs outstanding for bank i in month t, τ is the month in which institution i faces a downgrade of its short-term credit rating, and $Downgrade_{i,\tau+j}$ is a dummy variable that equals one for bank i at date $t = \tau + j$. We estimate 11 coefficients on such dummy variables, for $j \in \{-5, ..., 5\}$.

We report the estimated coefficients in Table X. As can be seen in column (1), the occurrence of a downgrade is associated with a significant drop in CD funding outstanding, starting in the month of the downgrade. Restricting attention to downgrades at the bottom of the rating scale (F2 to F3, or lower) in column (2), the drop in CD funding is larger in magnitude and more persistent. The economic magnitude of the drop is large, since CD funding gets cut by about 63%, which falls within our definition of dry-ups. We complete our analysis in column (3) by comparing the timing of rating downgrades with the timing of dry-ups. We find that credit ratings drop significantly one month before dry-ups occur. However, ratings are not the only public news that can trigger dry-ups. Indeed, the drop in rating becomes economically and statistically more significant after dry-ups occur.

D. CD Market Reentry after Dry-Ups

Finally, as a last piece of evidence in favor of theories based on heterogeneity across lenders, we highlight that issuers facing a full dry-up never re-enter the market (except in one case) even though the banks still operate. This is consistent with CD investors seeking information-insensitive securities and not considering as safe any further CDs issued by institutions that faced a dry-up. Instead, if dry-ups were associated with high-quality banks self-selecting out of the market, these banks would be expected to re-enter the market after market conditions have normalized.

Table X

Credit Rating Downgrades and CD Funding

This table estimates the effect of short-term credit rating downgrades on CD funding. In columns (1) and (2), the log of the amount of CDs outstanding for each bank is regressed on issuer and time fixed effects and on a set of dummy variables at dates $\tau + j$, for $j \in \{-5, ..., 5\}$, equal to one if the bank's credit rating is downgraded at date τ. Column (2) restricts attention to downgrades in the lowest part of the Fitch rating scale (F2 to F3, or lower). In column (3), the short-term credit rating of a bank is regressed on a set of dummy variables equal to one at date $\tau + j$ if the bank faces a dry-up at date τ. Standard errors, clustered at the bank level, are in parentheses. Note that standard errors in column (3) are close to equal, due to the low level of granularity of short-term credit ratings. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

	Dependent Variable: log CD Outstanding				Credit Rating	
	All Downgrades (1)		Only F2 to F3 or Lower (2)		Full Dry-Ups (3)	
Month $\tau - 5$	−0.112	(0.112)	−0.271	(0.254)	−0.039	(0.090)
Month $\tau - 4$	−0.049	(0.125)	0.180	(0.619)	−0.020	(0.090)
Month $\tau - 3$	−0.235	(0.134)	−0.196	(0.184)	−0.057	(0.090)
Month $\tau - 2$	−0.284	(0.225)	−0.234	(0.388)	−0.075	(0.090)
Month $\tau - 1$	−0.104	(0.062)	−0.627	(0.402)	−0.157*	(0.090)
Downgrade month τ	−0.303***	(0.100)	−0.691	(0.526)	−0.206**	(0.090)
Month $\tau + 1$	−0.295**	(0.135)	−0.803*	(0.388)	−0.209**	(0.090)
Month $\tau + 2$	−0.315*	(0.151)	−1.445***	(0.254)	−0.201**	(0.090)
Month $\tau + 3$	−0.201	(0.144)	−0.994***	(0.297)	−0.237***	(0.090)
Month $\tau + 4$	−0.183	(0.125)	−1.164**	(0.390)	−0.300***	(0.090)
Month $\tau + 5$	−0.097	(0.121)	−0.702***	(0.056)	−0.312***	(0.090)
Issuer fixed effect	Yes		Yes		Yes	
Month fixed effect	Yes		Yes		Yes	
Adj. R^2	0.137		0.136		0.233	
N. Obs.	8,297		8,297		10,459	

VI. Reallocation of Funds during Stress Episodes

The absence of a market freeze (total market volume remains stable) and the occurrence of bank-specific dry-ups together suggest that funds are reallocated in the cross-section during stress episodes. We study reallocation to provide additional evidence on the informational content of funding patterns.

A. Bank Borrowing as a Function of Quality

We shift our attention from banks that face dry-ups to banks that increase their CD funding. If CD lenders value information-insensitive debt securities, they should reallocate their funds to such CDs when dry-ups occur, in which case high-quality banks should increase reliance on CD funding in times of stress. If, instead, adverse selection is driving the allocation of funds, high-quality banks should reduce reliance on wholesale funding during such episodes. We study whether banks whose CD funding grows faster than the aggregate market are high-quality banks, that is, banks that will make more profitable use of these funds as measured by an increase in ROA in the future. We find strong evidence that this is indeed the case. This result further suggests that monitoring by informed lenders, not adverse selection, explains the allocation of funds in the market.

We start by comparing the growth in CD issuance by each bank to the growth in the aggregate CD market. At a monthly frequency, we compute E_{it}, the growth rate in issuance by bank i in excess of the growth rate in issuance at the market level,

$$E_{i,t} = [\log(CD_{i,t}) - \log(CD_{i,t-1})] - [\log(CD_{m,t}) - \log(CD_{m,t-1})], \tag{5}$$

where $CD_{i,t}$ is the amount of CD outstanding by issuer i at the end of month t and $CD_{m,t}$ is the aggregate size of the CD market in that month. We drop observations for which $CD_{i,t-1}$ is below a threshold of EUR 10 Mn. We also drop observations for issuers that enter the CD market for the first time.

We proceed in two steps. First, we check whether high and positive values of $E_{i,t}$ forecast future increases in ROA. If true, this would mean that banks whose CD funding grows more are able to make productive use of these funds, and funds flow to such banks regardless of whether there are dry-ups in the market. Second, we test whether the reallocation of funds toward better performing banks is stronger at times when dry-ups occur in the market.

We construct a dummy variable $I_{i,t}$ that equals one for any issuer i in month t if $E_{i,t}$ is above some percentile α of the distribution of $E_{i,t}$ in the same month, and zero otherwise. We provide results for both $\alpha = 50\%$ and $\alpha = 25\%$, that is, we consider only those banks that are above the median and in the top quartile in terms of the growth in their CD funding relative to the market. We estimate the probit model

$$\begin{aligned}\Pr(I_{i,t} = 1|X_t) = \Phi(&\beta_0 \Delta ROA_{i,t} + \beta_1 Controls_{i,t-1} + \beta_2 Controls_{c,t-1} + FE_c \\ &+ FE_m),\end{aligned} \tag{6}$$

where $\Delta ROA_{i,t} = ROA_{i,t} - ROA_{i,t-1}$ is the change in ROA between the end of the previous year (observable at the time of the dry-up) and the end of the current year (unobservable at the time of the dry-up). We include bank- and country-level controls as well as country fixed effects. In contrast with previous regressions, we run this regression at the monthly frequency, because we want to isolate higher frequency changes in CD funding, particularly those that take place when the CD market is stressed as measured by the occurrence of bank-specific dry-ups. To account for the fact that past balance sheet characteristics may be more informative about the early months of each year (and, symmetrically, late quarters of a year may correlate more with future balance sheet characteristics), we include month fixed effects, FE_m, for 11 out of 12 months. The fact that we focus on monthly variation in CD funding is also the reason we

Table XI

Reallocation of Funds after Dry-Ups

This table provides estimates of the probit model in equation (6). The dependent variable equals one for an issuer in a given month if its excess issuance over the market (defined in equation (5)) is above a threshold α. Columns (1) and (2) are for $\alpha = 0.5$ (50% of institutions with the largest excess issuance) and columns (3) and (4) are for $\alpha = 0.25$ (25% of institutions with the largest excess issuance). In columns (2) and (4), Δ ROA is interacted with dummy variables that equal one if *Stress Index* (defined in equation (1)) is in the second, third, or fourth quartile of its distribution. Each specification includes fixed effects for 11 out of 12 months. Control variables include size, ROA, impaired loans over total loans at $t-1$, book equity over total assets, bank short-term credit rating, and sovereign CDS spread. Standard errors, clustered at the bank level, are in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Dependent Variable: Prob. of CD Issuance in Excess of the Market				
	$\alpha = 0.5$		$\alpha = 0.25$	
	(1)	(2)	(3)	(4)
Δ ROA	0.025***	0.019**	0.033**	0.017***
	(0.005)	(0.009)	(0.014)	(0.006)
Δ ROA * Stress Index in Quartile 2		−0.003		0.008
		(0.016)		(0.006)
Δ ROA * Stress Index in Quartile 3		0.033***		0.039
		(0.012)		(0.033)
Δ ROA * Stress Index in Quartile 4		0.048**		0.030**
		(0.020)		(0.015)
Controls	Yes	Yes	Yes	Yes
Country fixed effect	Yes	Yes	Yes	Yes
Month fixed effect	Yes	Yes	Yes	Yes
N. Obs.	10,979	10,979	10,979	10,979

use $\Delta ROA_{i,t}$ as an independent variable, rather than as a dependent variable as in the previous section. Finally, Φ denotes the c.d.f. of the standard normal distribution.

Estimates are provided in Table XI for threshold values $\alpha = 0.5$ (column (1)) and $\alpha = 0.25$ (column (3)). The estimated coefficients are positive and significant at the 1% or 5% level. This means that, regardless of whether bank-specific dry-ups occur in the market, banks whose CD funding grows faster than the market are banks that increase their future ROA, that is, that tend to make more productive use of the funds they receive.

B. Focusing on Times of High Market Stress

We test whether the reallocation effect is stronger during periods in which bank-specific dry-ups occur in the market. Theory suggests that information asymmetries are larger in times of stress, possibly increasing adverse selection and reducing the informational content of dry-ups. If this is the case, high-quality banks should reduce borrowing in times of stress, thus lowering the baseline coefficient in Table XI. In contrast, high-quality banks should increase borrowing if lenders reallocate funds to other information-insensitive securities. We reestimate equation (6) after including interaction terms between $\Delta ROA_{i,t}$ and dummy variables taking a value of one if *Stress Index*, defined in equation (1), is in the second, third, or fourth quartile of its distribution (i.e., highest values of *Stress Index*).

We present the estimates in columns (2) and (4) of Table XI. The base coefficient on ΔROA, corresponding to periods in which *Stress Index* is the lowest, remains positive and significant. Coefficients on the interaction terms, however, indicate that this effect is much larger in magnitude at times when *Stress Index* is high, that is, when it is in its third or fourth quartile. This is indicative of the fact that the reallocation of funds toward banks that will increase performance in the future is amplified in times of financial stress. The economic magnitude of this effect is large—the estimated coefficient on the interaction term corresponding to highest market stress is twice as large as that on the unconditional coefficient β_0.[14]

These results are of particular interest for two reasons. First, they provide additional, strong evidence against adverse selection. Indeed, they go against the main prediction of adverse selection models that higher-quality banks self-select out of the market. In addition to showing that they do not exit the market, we show that they instead increase funding. They do so particularly in times of high market stress, times when information asymmetries are arguably more severe.

Second, these results are compatible with a model in which lenders value debt securities as long as they remain information-insensitive and reallocate funds accordingly. This is consistent with the fact that reallocation toward high-quality banks is stronger in times of high market stress. However, the fact that increases in CD funding predict better future performance shows that reallocation is, at least partially, informed. This suggests that informed lenders not only monitor low-quality issuers, but also identify well-performing institutions, based on unobserved characteristics.

Finally, we are unable to find any significant relation between the reallocation of funds toward high-quality banks and the spread between the rate paid by low-rated issuers relative to high-rated issuers. In columns (3) and (6) of Internet Appendix Table IAIII, we regress *Stress Index*, which captures the magnitude of funds reallocated due to dry-ups, on contemporaneous and future spreads. If reallocation drives interest rates down for high-rated banks, the spread should widen when dry-ups occur or right after. Estimating this regression at a weekly frequency, both in levels and in first-differences, we

[14] The results in Table XI are robust to endogeneity tests. As in Section B, we find that the effect is similar in magnitude across banks that do or do not rely heavily on CD funding. It is also robust to replacing the dependent variable by changes in nonperforming loans. Since the endogeneity concern (i.e., that improvements in bank performance could be due to the inflow of CD funding) is less severe than in Section IV, we do not report these regression coefficients.

are unable to find any such statistically significant relation. A possible interpretation is that the magnitude of funds reallocated is small relative to the size of the market and therefore does not affect prices. The absence of a significant relationship may also be due in part to the low level of granularity of our interest rate data. Further research on reallocation is therefore needed.

VII. Conclusion

We draw three main conclusions from our study on CD funding. First, wholesale funding dry-ups are mostly bank-specific and driven by information about future bank quality. This is in contrast with the view that wholesale funding markets are inherently subject to market-wide disruptions. Second, the cross-sectional allocation of funds in wholesale funding markets is not driven primarily by adverse selection between lenders and borrowers in times of stress. Third, this fund allocation is consistent with models based on heterogeneity between informed and uninformed investors. In such models, bank debt derives value from being information-insensitive, and dry-ups occur when debt turns information-sensitive. Such theories allow us to explain actual patterns in the data: funding adjustments occur primarily through quantities, not through prices, banks that face dry-ups are those whose performance will deteriorate in the future, and banks receiving more funds during stress episodes are those whose profitability will improve.

The bank-specific nature of dry-ups helps us understand the resilience of wholesale funding markets. As such, our results do not support one of the main premises on which new regulation on liquidity coverage ratios is based. However, since our analysis disregards the negative externalities triggered by dry-ups, we cannot draw any definite conclusion about the soundness of these regulatory tools. Similarly, we leave the study of the implications of our results for optimal disclosure or opacity to future work.

From our analysis, one can also draw lessons for central banking. We show that high-quality banks are still able to access wholesale funding in times of stress, and eventually to increase funding. They are thus less likely to require funding from the central bank. This finding is in contrast with the received theory on the lender of last resort, according to which central banks should lend only to solvent institutions facing temporary liquidity needs. However, it is consistent with recent empirical evidence by Drechsler et al. (2016), who find that central bank funding mainly benefited weakly capitalized banks during the recent financial crisis.

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Appendix

Table AI
Variable Definitions

This table defines the variables used in the empirical analysis. The CD data, obtained from the Banque de France, are complemented with data from Bankscope. Definitions of the balance sheet variables are obtained from the Bankscope user guide. The "id" code is the index number in Bankscope. Variables related to issuer profitability and asset quality are winsorized at the 1st and 99th percentiles.

Variable	Definition	Data Source
Issuer Balance Sheet		
Assets	Total assets (id: 11350).	Bankscope
Book equity	Common Equity (id: 11800).	Bankscope
Total regulatory capital	Tier 1 + Tier 2 capital, as a percentage of risk-weighted assets (id: 18155).	Bankscope
Loans	Gross loans (id: 11100).	Bankscope
Customer deposits	Total customer deposits: Current + Savings + Term (id: 11550).	Bankscope
Repos and cash collateral	Includes all securities designated for repurchase or cash received as collateral as part of securities lending (id: 11565).	Bankscope
Loans from central bank and other banks	Deposits from banks (id: 11560)	Bankscope
Issuer Profitability and Asset Quality		
Net income	Net income (id: 10285).	Bankscope
ROA	Return on average assets (id: 4024).	Bankscope
Impaired loans/Gross loans	Impaired Loans over Gross Loans (id: 18200).	Bankscope
Impaired loans/Equity	Impaired Loans over Equity (id:4037).	Bankscope
Market Data		
Short-term credit rating	Encoded on a scale from 1 to 5 ("B"=1; "F3"=2; "F2"=3; "F1"=4; "F1+"=5)	Fitch Ratings/ Moody's or S&P if Fitch unavailable
Stock price	End-of-day stock price	Bloomberg
Sovereign CDS spread	5-year CDS spread (mid-quote)	Bloomberg

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Appendix S1: Internet Appendix.