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* Views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank.

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The 'new normal' during normal times – liquidity regulation and conventional monetary policy

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Abstract

We analyze the impact of a requirement similar to the Basel III Liquidity Coverage Ratio (LCR) on conventional monetary policy implementation. Combining unique data sets of Dutch banks from 2002 to 2005, we find that the introduction of the LCR impacts banks' behaviour in open market operations. After the introduction of the LCR, banks bid for higher volumes and pay higher interest rates for central bank funds. In line with theory, banks reduce their reliance on overnight and short term unsecured funding. We do not observe a worsening of collateral quality pledged in open market operations. Thus, to correctly anticipate an open market operation's effect on interest rates, monetary policy requires central banks to consider not only the size of the operation, but also how it impacts banks' liquidity management and compliance with the LCR.

Keywords: Liquidity regulation, monetary policy implementation, financial intermediation, banks, open market operations
JEL classification: G18, G21, E42

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1. Introduction

Central banks around the world are discussing how to revise monetary policy frameworks. Although the current Covid-19 pandemic has postponed the return to normal market operations, an important question that arises when considering taking steps towards a normalization[1] of monetary policy is how liquidity regulation interacts with monetary policy implementation in the absence of large-scale open market operations. Shedding light on this question is the purpose of this paper.

Liquidity risk has always been a core risk in banking. The maturity mismatch between assets and liabilities imply that banks run a distinct possibility (Diamond and Dybvig (1983)). In the early days of international cooperation on prudential bank regulation undertaken by the Basel Committee on Banking Supervision, credit risk and liquidity risk were seen on equal footing. As documented by Goodhart (2011), the attention then shifted to developing guidance on credit risk as agreeing on liquidity risk was seen as too difficult a venture. At the time, regulation ignored systemic considerations entirely.

The Global Financial Crises (GFC) in 2008-2010 highlighted the importance of (systemic) liquidity and led the Basel Committee to develop a liquidity buffer for banks – the Liquidity Coverage Ratio (LCR). The LCR requires banks to hold sufficient high quality liquid assets to cover their estimated net cash outflows over a 30-day stress scenario. This requirement was implemented in 2015 in a market flush with excess reserves. For this reason the impact of the newly introduced constraint on banks was difficult to measure (cf Schertler (2010),Fuhrer et al. (2017), Banerjee and Mio (2018)). Furthermore, the analysis of the implementation is often from a micro prudential point of view.

Liquidity regulation, however, also interacts with monetary policy in important ways (Bech and Keister, 2017; Körding and Scheubel, 2018). More specifically, Bech and Keister (2017) theorize that, in order to avoid a shortage in LCR liquidity, banks

[1] We define normal monetary policy to have policy rates in line with the 2 percent longer-run inflation objective without any central bank liquidity stimulus programmes. Monetary policy normalization could have two phases in which the central bank would be, first, raising the policy target rate closer to more normal levels, reflecting the ongoing improvement in the economy and, second, gradually reduce the central bank's balance sheet as it unwinds the asset purchase policies put in place during the GFC (cf. New York Fed president John C. Williams, https://www.newyorkfed.org/newsevents/speeches/2018/wil180928).

borrow more from the central bank and that they bid more aggressively at central bank auctions to obtain this higher volume. Moreover, banks will rely less on the short run overnight markets and more on longer term markets.

Since very few countries had *quantitative* liquidity regulations in place before the GFC, the extant analysis assesses the effect of the LCR in abnormal interbank markets flushed with liquidity. The Netherlands introduced such a quantitative liquidity requirement as early as 2003 – well before the crisis and in a period with normal monetary policy. That is, monetary policy was characterized by policy rates in line with the 2 percent longer-run inflation objective and an absence of central bank liquidity stimulus. Furthermore, the Dutch LCR, or DLCR, served as input for the Basel LCR and hence it is very similar. The implementation of the DLCR in the Netherlands thus provides a unique chance to study the impact of a quantitative liquidity requirement on banks' behaviour.

We contribute to the literature by being the first to study how banks adjust to the introduction of quantitative liquidity constraints in terms of volume and pricing in open market operations, in terms of collateral quality pledged in open market operations, and in terms of volume and maturities preferred in the interbank market. We test the model proposed by Bech and Keister (2017) with a comprehensive data set including individual banks' quantitative liquidity requirements, volumes and interest rates bid by Dutch banks in European Central Bank (ECB) open market operations, collateral quality pledged to the ECB, minimum excess reserves held, and the activity of banks on the unsecured interbank market. We run panel data regressions to compare Dutch banks – subject to liquidity constraints – with their European peers unconstrained at the time. We then study whether the liquidity requirements affects monetary policy implementation.

Our results suggest that, in line with theory, banks adjust their behaviour in central bank open market operations and that the introduction of liquidity requirements affects monetary policy implementation. More specifically, banks bid for higher volumes and higher rates to obtain funds from the ECB during and after the implementation of the DLCR. A takeaway from our results is also that liquidity requirements did not impact the excess reserves that banks held during or after the implementation of the DLCR in comparison to European peers.

A key concern raised in the debates around the introduction of the LCR was that banks would pledge lower quality collateral to the Eurosystem to save their

higher quality collateral to fulfill the LCR. Our analysis shows that, against expectations, banks do not reduce the quality of the collateral pledged at the central bank. Since we do not have data on the European level for comparison, our results on collateral are not as strong as the those for volumes and prices. Regarding the interactions in the unsecured interbank market we find, in line with expectations, that banks' reliance on short term interbank funding decreases immediately after the implementation of the DLCR.

These results add to the existing studies – using data from the GFC and beyond – showing that the introduction of liquidity constraints changes bank behaviour. Germany introduced its liquidity requirement in 2007, right before the GFC, and Schertler (2010) finds that most banks in Germany reduce their issuance of long-term loans when constrained by the liquidity requirement. Fuhrer et al. (2017) show that the introduction of the LCR in Switzerland impacted the pricing of highly liquid assets that qualify to meet the LCR requirement. Banerjee and Mio (2018) find that banks increased funding from more stable sources while they reduced the reliance on short-term intra-financial loans and other short-term wholesale funding, in response to the introduction of the UK requirements in 2010. A major shortcoming of these studies, however, is that the liquidity requirements have been implemented right before or right after the crisis. Especially Banerjee and Mio (2018) are likely to mainly identify the effects of unconventional monetary policy rather than liquidity regulation.

We also expand the existing literature on the Dutch liquidity requirement which tested the impact of the introduction of the DLCR during the GFC so far. None of these previous studies fully explore how banks react to the introduction of liquidity regulation during times with normal monetary policy. Bonner and Eijffinger (2016) analyze the impact of the DLCR on interbank money markets and banks' lending to the real economy. The authors find that the DLCR led to a premium on long-term interbank loans and caused banks to borrow more, and lend less long-term loans. Duijm and Wierts (2016) analyze how banks adjust their balance sheets to meet the liquidity requirement following liquidity shocks. The authors find that banks mainly react by increasing the share of long-term funding, while the effect on liquid assets is insignificant. A study by De Haan and den End (2013) shows that most banks hold more liquid assets than strictly necessary under the regulation. More solvent banks hold fewer liquid assets against their stock of liquid liabilities, suggesting an

interaction between capital and liquidity buffers.

Finally, our paper is also related to the literature on banks' bidding behaviour in open monetary operations. Nyborg et al. (2002) provide a first account of how banks behave in the ECB main refinancing operations with variable rate auctions. They find that the minimum bid rate and the secondary market rates influence bidder behaviour and the effectiveness of the auction. However, private information and the winner's curse do not influence the auctions. We add to this stream of literature by showing that the introduction of liquidity requirements influences the bidding behaviour of the banks in open market operations as well. Banks become more interested in obtaining funds in open market operations, and bid higher rates to get allotted liquidity. This in turn increases the efficiency of the auctions and it reduces the chances of under-pricing.

The remainder of this paper is structured as follows: Section 2 explains the theory, Section 3 describes the institutional background and the data used, Section 4 presents the method and results, and, finally, Section 5 concludes.

2. Theory

Our research objective is to understand how liquidity requirements influence conventional monetary policy implementation and this section introduces the theory and hypotheses our research is based on. We first look at whether banks adjust their behaviour in central bank open market operations once they become subject to liquidity requirements. Open market operations, in which banks can bid for liquidity, are the channel through which the ECB injects reserves into the banking sector. If banks do not bid or bid insufficiently to obtain these funds, then banks have the option to obtain funds in the secondary market, that is borrow from other banks. The latter option is more expensive than when obtaining funds from the central bank. Bech and Keister (2017) propose that to avoid a shortage in LCR liquidity, banks will borrow more from the central bank. And because the supply of reserves is limited, banks have to bid more aggressively at central bank auctions to achieve this higher volume. The implementation of the LCR in the Netherlands makes banks be short liquidity, and therefore these banks have stronger incentives to bid in open market operations than (unconstrained) banks that are long liquidity. In the model developed by Bech and Keister (2017) all banks are constrained by liquidity requirements. Unlike them, we compare the special case of the Netherlands,

where banks are constrained by liquidity requirements, with banks in the remainder of the EU unconstrained by liquidity requirements. In line with theory, we propose to test the following hypothesis:

Hypothesis 1: Banks subject to liquidity requirements bid more aggressively and get higher amounts allotted compared to banks that are not subject to liquidity requirements.

Second, we look at excess reserves. These assets help banks to satisfy their LCR requirement. However, banks that hold excess reserves with the central bank, instead of other securities that qualify as high quality liquid assets (HQLA) for DLCR purposes, are foregoing profit making opportunities. Given this trade-off, the model of Bech and Keister (2017) does not predict banks to hold more excess reserves at the central bank after the implementation of the liquidity requirement. We therefore formulate the following hypothesis:

Hypothesis 2: Banks subject to a liquidity requirement do not hold more excess reserves during and after the implementation of the DLCR.

Third, we look at whether banks adjust their reliance on short term funding in the interbank unsecured market. The risk of a reserve shortfall and an LCR shortfall is the same for all banks because the interbank market redistributes overnight and long term funding and is available for all market participants. We expect that banks subject to the LCR have a larger incentive to obtain longer term funding (above 30 days) in the unsecured interbank market because with an LCR, funds with a maturity above 30 days are essential to satisfy the requirement. The model of Bech and Keister (2017) predicts that in the unsecured interbank market, banks subject to the LCR have less demand for short term funding and more demand for longer term funding.

Hypothesis 3: Banks decrease the share of the short-term funding and adjust their funding mix as a consequence of the introduction of the DLCR.

We extend our discussion to collateral used in open market operations with two extra hypothesis. According to Körding and Scheubel (2018), banks constrained by the LCR have an incentive to borrow from the central bank against non-HQLA collateral, and have an incentive to invest in safe liquid assets. Non-HQLA collateral is of lower credit quality than HQLA collateral, so this effect would translate into a decrease in overall collateral quality pledged to the central banks in open market operations. We test this by formulating the following hypothesis:

Hypothesis 4: The quality of collateral pledged to the Eurosystem deteriorates after the implementation of liquidity requirements.

Without an LCR requirement, only the size of an open market operation matters for interest rates. However, with an LCR, the details of the operation matter, for instance, which assets are used. The ECB accepts both HQLA and non-HQLA as collateral. While both non-HQLA and HQLA can be used to satisfy reserve requirements, only using non-HQLA helps a bank to satisfy its LCR requirement. Thus, comparing banks subject to a liquidity requirement to other banks, the model of Körding and Scheubel (2018) predicts the former to use a higher share of non-HQLA collateral in central bank operations to obtain central bank reserves.

Hypothesis 5: Banks subject to the LCR pledge a higher share of non-HQLA assets in central bank operations.

3. Institutional Background

3.1. The LCR

The Liquidity Coverage Ratio (LCR) is defined as a ratio with the numerator representing the amount of high quality liquid assets (HQLA), i.e., assets that can be easily and immediately converted into cash at little or no loss of value (BCBS (2013)). Liquid assets consist of cash, central bank reserves, and, to a certain extent, marketable securities, sovereign debt, and central bank debt. The denominator is the net cash outflow within 30 days, which is the difference between outgoing and incoming cash flows. The LCR is defined as:

$$LCR = \frac{High\ Quality\ Liquid\ Assets}{Cash\ outflows - Cash\ Inflows} \geq 100\%, \tag{1}$$

where the cash outflows are subject to prescribed run-off rates and the cash inflows are subject to prescribed haircuts in order to assign these items a liquidity weight. The similarity between Basel III and the existing Dutch liquidity framework makes it possible to use the Dutch liquidity coverage ratio (DLCR) as a comparable measure, also in line with previous studies by Bonner (2012) and Duijm and Wierts (2016).

3.2. The Dutch LCR

In contrast to liquidity requirements in other jurisdictions, the DLCR was introduced in 2003, well before the crisis. Similar to the LCR, the DLCR is based on classic liquidity "coverage" considerations, used by banks and some regulators:

$$DLCR = \frac{Actual\ Liquidity}{Required\ Liquidity\ within\ 30\ days} \geq 100\%. \tag{2}$$

Actual Liquidity (AL) is defined as the stock of liquid assets minus haircuts plus recognized cash inflows weighted by degree of liquidity. Required Liquidity (RL) consists of assumed calls on contingent liquidity lines, assumed withdrawals of deposits as well as assumed drying up of wholesale and derivative funding. Apart from cash, government bonds and highly rated covered bonds, the DLCR additionally allows banks to include most central bank eligible securitizations as part of their liquidity buffer while the LCR allows structured products only to a limited extent. Contrary to the LCR, the DLCR does not distinguish between "stable" and "less stable" retail deposits which have different run-off rates under stress and are classified according to a set of predefined conditions.

On the whole, the differences between the DLCR and the LCR are negligible. Given that the LCR is stricter with regard to the definition of liquid assets, while the DLCR applies considerably higher outflow rates and haircuts, the differences between the two regimes are likely to cancel each other out to a large extent.[2]

3.3. Monetary policy of the European Central Bank between 2002 and 2004

There are various ways for a central bank to implement monetary policy. We consider the period between 2002 and 2004 which we study to be a period with *normal monetary policy*. In contrast to the period after October 2008, the ECB maintained a liquidity deficit regime, meaning that central bank reserves were scarce and central banks used conventional monetary policy instruments. For the ECB, this includes 1) open market operations, 2) standing facilities, and 3) minimum reserve requirements.[3] All these instruments are aimed to steer the overnight interest rate that is used as operating target for monetary policy implementation.

Open market operations play an important role in steering interest rates, managing overall market liquidity and signalling the monetary policy stance. There are two forms of open market operations, namely Main Refinancing Operations (MRO)

[2] This is especially true since the new compromise, described in BCBS (2013).

[3] Since 2009, the ECB has implemented various non-standard monetary policy measures, such as asset purchases. Since they fall outside our time period, we can ignore these. See ECB (2012), Eser and Schwaab (2016) and Zabala and Prats (2020) for further details on these non-standard measures.

and Long Term Refinancing Operations (LTRO). During 2002 and 2004 the ECB conducted MRO where banks could borrow cash against collateral for 2 weeks, and LTRO where banks could borrow secured for up to 3 months. Credit institutions can borrow liquidity from the ECB at either a variable interest rate by bidding (before 2009) or at fixed interest rates (after 2009). In the former case, the allotted amount is fixed beforehand, which implies that funds are distributed to the highest bidder until the total amount of liquidity to be allotted is depleted. At the lowest interest rate level accepted, if the aggregate amount bid exceeds the remaining amount to be allotted, the remaining amount is allocated pro-rata among the bidders. By setting the interest rate or by creating expectations regarding the interest rate, the ECB aims to steer the rates in money markets.

Most central banks – among which the ECB as well – require credit institutions to hold a minimum amount of reserves with them. An institution's reserve requirement is determined by multiplying the reserve base with the reserve ratio. The reserve base includes retail deposits and a selection of short-term liabilities, while the ECB's reserve ratio was set at 2% during the sample period.[4] Compliance with minimum reserve requirements is determined on the basis of banks' average daily balances on the central bank reserve accounts over the reserve maintenance period. The main function of the minimum reserve requirement is to stabilize money market rates. Once liquidity requirements are introduced for banks, reserves have therefore a double purpose: they count towards the LCR and they count towards full-filing the minimum reserve requirement.

4. Empirical Analysis

4.1. Data

In order to analyze the effects of a quantitative liquidity requirement on banks' behavior, we bring together data on 1) DNB's monthly prudential liquidity reporting since 2003; 2) bilateral transaction data in the unsecured interbank market for different maturities; 3) central bank minimum reserve requirements and holdings 4) data from ECB open market operations such as allotted and bid volumes and interest rates; 5) collateral quality data posted by Dutch banks to the central bank,

[4] The ECB reserve ratio was set at 2% at the start of the ECB on 1 January 1999 and it was reduced one time to 1% on 18 January 2012.

and 6) bank control variables such as risk indicators and other measures calculated from the banks' balance sheet.

For the DLCR, we use monthly data from January 2002 to December 2004 from DNB's regulatory liquidity reporting. With respect to the unsecured interbank money market, we use the same raw data as Arciero et al. (2016). They describe how loans can be identified, and thus, how volumes and prices can be extracted from the observable payment flows between banks. The authors build on the seminal paper by Furfine (1999), and improve the algorithm to resolve its limitations, and include maturities of up to one year.[5] We use a sample of 10 banks, covering all the banks active in the Dutch interbank market at the time. Note that the Dutch market is highly concentrated and hence we include almost all of the banking activity.

In the period we study, banks had to hold a minimum of 2% of their customers' deposits, at their national central bank as reserves. For the Dutch market we collected data from 10 banks, representing approximately 8% of the total reserves in the Eurosystem. We use the reserves required and reserves held to compute the banks' excess reserves on a daily basis.

Data on open market operations such as MRO and LTRO is collected for the banks active in ECB auctions between January 2002 and December 2004. For comparison we use the European aggregated averages published by the ECB consisting of the weighted average bid rate and the volume weighted volumes bid and allotted.

The data on collateral is collected by DNB for the monetary statistics of the Eurosystem. We use data covering the same sample period from January 2002 to December 2004 and it distinguishes collateral types, ratings and amounts.

We also include a number of bank-specific controls, described in Table 1, such as institutions' capital solvency ratio (capital in percentage of RWA), profitability (net income in percentage of total assets), leverage as well as loan loss provisions (as percentage of total assets) and the size of the bank as the log of total assets. For all balance sheet measures we use monthly data per bank from January 2002 to December 2004 from DNB's prudential reporting.

[5] As well as being applied in the US using Fedwire (Demiralp et al., 2006; Ashcraft and Bleakley, 2006), the algorithm has also been applied in Norway (Akram and Christophersen (2010)), and Germany (Bräuning and Fecht (2016)).

Table 1: **Summary statistics.** All values except for Total Assets are expressed in percentage points. Total Assets is shown in natural logs. Data is monthly and ranges from 2 January 2002 to 31 December 2004.

Variables	Obs	Mean	Median	Min	Max
BIS Capital Ratio	396	15.21	11.10	9.11	46.05
Equity to Total Assets	396	5.43	4.70	2.47	20.32
LLP to Total Assets	396	0.82	0.64	0.03	2.97
Asset Growth	396	1.51	0.77	-11.12	33.24
Cost to Income	396	75.46	68.8	11.59	150.78
Return on Assets	396	0.09	0.09	-0.5	1.44
ln Total Assets	396	16.94	16.06	13.55	20.29
Deposit to Loans	396	0.31	0.25	0.03	1.55

4.2. Methodology

For the empirical analysis in this paper, we follow Bonner (2012) as well as Bonner and Eijffinger (2012), and therefore, the baseline regression takes the following form:

$$\begin{aligned} Y_{i,t} = \beta_0 + \beta_1 (DLCR\, implemented)_t + \beta_2 (DLCR\, transition)_t + \\ \beta_3 Excess\ Reserves_{i,t-1} + \beta_4 Bank\ Controls_{i,t-1} + \mu_i + \epsilon_{i,t}, \end{aligned} \tag{3}$$

where $Y_{i,t}$ comes in six distinct variants that are described individually in the following subsections of this section. The right hand side of the model reflects common practice when estimating a panel model with fixed effects μ_i. It includes the dummy variables $DLCR\, transition_t$ which is equal to 1 between 1 April 2003 and 31 December 2003, and 0 otherwise, and $DLCR\, implemented_t$ which is equal to 1 between 1 January 2004 and 31 December 2004, and 0 otherwise. These dummies aim to identify whether banks changed their behavior during the transition to the DLCR or afterwards when the DLCR became mandatory and fully implemented by all banks in the sample.

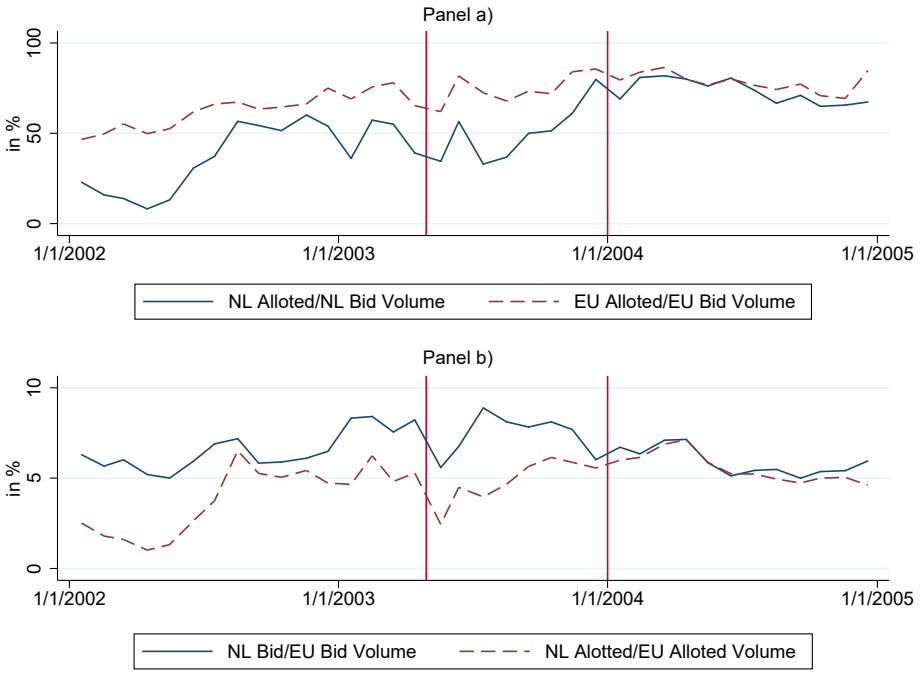
We run the regressions including $Controls_{i,t-1}$. These are defined following Liedorp et al. (2010) and include an institution's lagged capital solvency ratio (capital in percentage of RWA), profitability (net income in percentage of total assets), fulfillment of the average reserve requirement, leverage as well as RoE, RoA and loan loss provisions (as percentage of total assets).

4.3. Bidding behaviour in open market operations

We study banks' success rate compared to European peers in terms of volumes bid and allotted in open market operations. First we plot the variables and then we proceed with regressions and discussion of results.

Panel a) of Figure 1 shows the evolution of the allotted volumes as share of bid volumes for Dutch and European peers. In the beginning of 2002, Dutch banks are allotted around 30% of the volumes they bid for, while European banks are allotted more than 50% of what they bid for. The graph shows how the allotment difference decreases over time after the liquidity requirement for Dutch banks is introduced in April 2003. Once the liquidity requirement is implemented and becomes mandatory for all Dutch banks in January 2004, the difference in ratios becomes negligible. In a similar way, Panel b) of Figure 1 illustrates the Dutch banks' share in the European bid and allotted volumes becoming gradually aligned, especially in 2004. In 2002, the Dutch bid volume starts at around 7%, while Dutch banks get under 5% allotted. However, in 2004 the difference between these ratios decreases indicating that Dutch banks are competing more in ECB open market operations after the introduction of the liquidity requirement.

Figure 1: **Bidding behaviour in central bank auctions.** Panel a) shows the average success rate in obtaining liquidity in ECB open market operations for Dutch banks and the average European peers. Panel b) illustrates the share of Dutch banks volume bid and allotted in the total Eurosystem volume bid and allotted via open market operations. The two vertical red lines mark the staggered introduction of the DLCR in the Netherlands; Between 1 April 2003 and 1 January 2004 we consider a transition periods as banks gradually start implementing the DLCR requirement. After 1 January 2004 the DLCR is fully implemented.



The graphs in Figure 1 show that unconditionally the Dutch banks seem to have become more similar to their European peers. However, other drivers might also be at play here. For example, monetary policy interventions might have changed over time. To test wether Dutch banks' bidding behaviour converged to their European banks we choose the difference between the two lines plotted in Panel a) of Figure 1 as the dependent variable in the first regression as presented in Equation 4 below:

$$\Delta\, Allotment\ Rate_{i,t} = Average\, Allotment\, Rate_{i,t} - Average\, EU\ Allotment\, Rate_{t}\ (in\ \%). \quad (4)$$

The results of the regression are presented in Table 2. Column 1 presents the base model with two dummies and with statistically significant results for DLCR implementation[6]. After the full implementation of the DLCR in January 2004, Dutch banks get allotted 18% more funds after the implementation of the DLCR compared to European peers. This effect is in line with our expectations and confirms *Hypothesis 1.*

In Column 2 we add the MRO dummy variable which is equal to 1 in a Main Refinancing Operation (MRO), and equal to 0 in a Long Term Refinancing Operation (LTRO) period. We would expect banks to prefer obtaining funds from MRO because they are cheaper while they also count for fulfilling the DLCR. The significant coefficient of MRO suggests that banks seek and get allotted 18% more funds during Main Refinancing Operations (MRO) in general. We also introduce an interaction between MRO and DLCR implemented to understand whether the introduction of the DLCR influences banks' preference for MRO. This seems the case as banks get allotted 10% more after the introduction of the DLCR in MRO.

This result is intuitive because both MRO and LTRO help banks comply with the DLCR requirement. LTRO funds are more costly however due to the term premium. Furthermore, in Column 3, we find a statistically significant relationship between the Δ *Allotment Rate* in OMO and excess reserves. In other words, banks with lower levels of reserves in excess of the minimum requirements obtained more funds from the ECB in OMO, however this behaviour is not linked to the introduction of the DLCR. Whether there is a link or not between the introduction of the DLCR and reserves held in excess, is tested in section 4.5.

We include robustness checks in Columns 4, 5 and 6 of Table 2 where we run pooled regressions with and without bank controls and the results remain qualitatively unchanged.

[6] The macro-economy remained stable during the time period we studied, and was not correlated with the banks included in the sample. Interest rates and money market rates were broadly stable, while GDP and unemployment rate remained within reasonable ranges without large fluctuations in the Netherlands or in the EU. ECB (2004).

Table 2: **Regression results for Δ *Allotment Rate* (i.e. volumes) in ECB tenders.** There are four independent variables out of which three are dummies. *DLCR implemented* and *DLCR transition* are dummies that are equal to one during the period when the DLCR is fully implemented, after 1 January 2004 and onward, and when the DLCR was partially implemented by banks, respectively, between 1 April and 31 December 2003. *MRO* is a dummy that is equal to 1 when the auction is a main refinancing operation and 0 when the auction is a long term refinancing operation. *Excess reserves* is the percentage of reserves held in excess of minimum requirements by the banks in the sample. The dependent variable Δ *Allotment Rate* is the difference between the allotment rate of the bank and the average EU allotment rate on a particular day and is defined in percentage points. The sample is from 2 January 2002 to 31 December 2004.

	(1)	(2)	(3)	(4)	(5)	(6)
DLCR_implemented	18.52***	9.66***	9.02***	9.87***	9.45***	10.18***
	(4.19)	(3.82)	(1.72)	(3.85)	(1.59)	(2.16)
DLCR_transition	1.00	0.57	0.85	0.61	1.26	1.44
	(2.80)	(3.09)	(1.63)	(3.06)	(1.60)	(2.36)
MRO		18.17***	18.04***	18.29***	18.18***	17.86***
		(1.52)	(1.12)	(1.35)	(0.63)	(1.54)
MRO X DLCR_implemented		11.45***	11.90***	11.28***	11.80***	11.62***
		(2.38)	(1.54)	(2.21)	(1.45)	(2.25)
Excess Reserves			-0.01**	-0.01**	-0.00*	-0.01*
			(0.01)	(0.01)	(0.01)	(0.01)
Constant	-279.90	-78.25	-45.82***	-81.96	-41.60***	-55.03***
	(405.91)	(410.07)	(1.06)	(405.93)	(0.39)	(16.11)
Observations	768	768	768	768	768	768
Number of banks	10	10	10	10	10	10
Bank FE	YES	YES	YES	YES	NO	NO
Bank Controls	YES	YES	YES	NO	NO	YES
r2 overall	0.26	0.36	0.33	0.36	0.33	0.34

*** p<0.01, ** p<0.05, * p<0.1, robust standard errors in parentheses

4.4. Rates bidding in open market operations

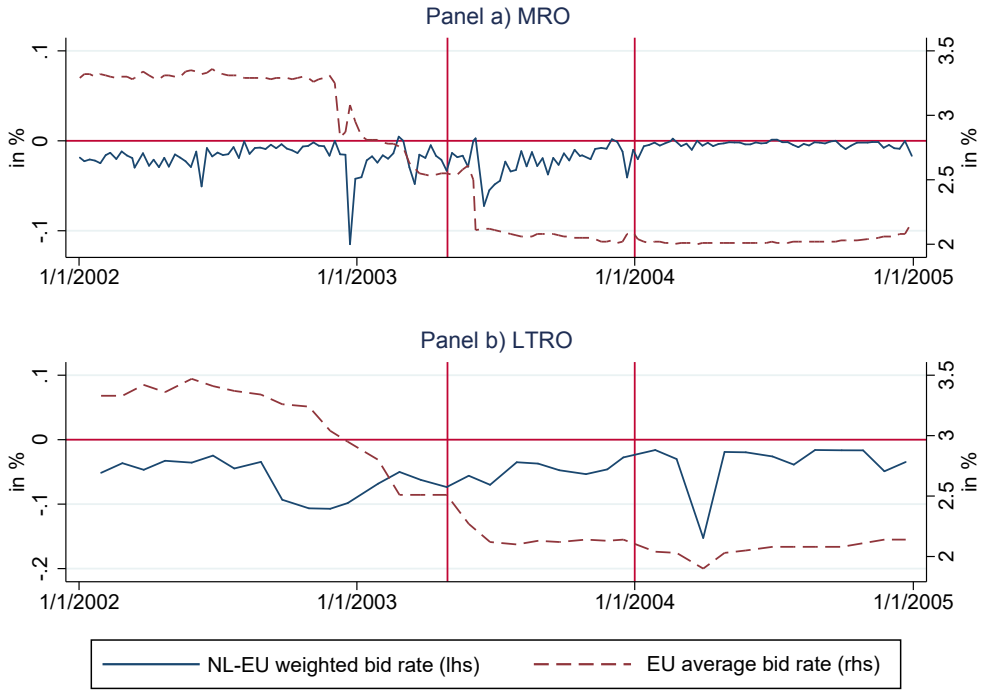
In the previous section we showed that banks' success rate in OMO increased when they are subject to the liquidity requirement. In this section, we study whether banks subject to the DLCR have been bidding rates above or below the EU peers in the open market operations.In Figure 2, we plot the difference between the interest rates bid by Dutch banks and European banks over time. Panel a) shows that Dutch banks start bidding higher rates for MRO. This effect is especially visible during 2004 once liquidity requirements are implemented. This aligns with Figure 1, and it explains why Dutch banks get higher amounts allotted. For LTRO in Panel b) this effect is not visible. This is an intuitive result since both MRO and LTRO borrowing help banks fulfil their liquidity requirement, but the LTRO are more expensive than MRO due to the term premium banks pay for the longer maturity of the LTRO funds. Another reason for why we do not observe an LTRO effect, is that banks have an alternative for longer term borrowing to fulfill the liquidity requirement. At the time banks could borrow long term funds in the unsecured interbank market which are also a cheaper alternative to LTRO (Bonner (2012)). We note that the short term borrowings in the unsecured interbank market are not a viable alternative for MRO, because they do not help fulfill the liquidity requirement. This also explains why banks are more interested in MRO than in LTRO.

Figure 2 shows the evolution of the bidding behaviour of Dutch banks compared to their European banks. We chose the blue line from this figure as the dependent variable in Equation 5. The blue line is the difference between the volume weighted average interest rate bid by Dutch banks and the EUR average bid rate as presented in words in Equation 5 below:

$$\begin{aligned} Tender\ Rate\ Difference_{i,t} = Volume\ Weighted\ Bid\ Interest\ Rate_{i,t} - \\ - EU\ Volume\ Weighted\ Bid\ Interest\ Rate_t\ (in\ \%). \end{aligned} \tag{5}$$

The statistically significant results shown in Table 3 suggest that for a given Dutch bank, the difference in the rate paid compared to the EU average increased by 1.3 basis points after the implementation of the DLCR. In terms of economic significance, this result shows a relative small increase in the price of banks' funding via the open market operations after the implementation of the DLCR. To put this

Figure 2: **Interest rates in ECB Open Market Operations.** Panel a) shows the evolution of interest rates in the Main Refinancing Operations (MRO). The dashed red line depicts the EU average bid rate. The blue line illustrates for each MRO the difference between the volume weighted average interest rate bid by Dutch banks and the EU average interest rate bid. In Panel b) the graph illustrates the evolution of the same metrics as in Panel a) but in the Long Term Refinancing Operations (LTRO). The two vertical red lines mark the two dates of the staggered DLCR implementation.



result into perspective, the banks in the sample constrained by the DLCR paid only approximately EUR 8 million extra for their funding from open market operations in 2004. Results are in line with *Hypothesis 1* and our previous expectations, and add to the explanation on why Dutch banks get higher volume allocations than their EU peers. Further, it seems that in general, for a given Dutch bank the difference in rate paid compared to EU peers is higher by 3.6 basis points in MRO. However this effect on the interest rate is not caused by the introduction of the DLCR, as it is shown by the statistically non-significant coefficient of the interaction between MRO and DLCR. No significant relationship is found between rates bid and the level of excess reserves held by banks after the DLCR implementation. To check robustness, we run pooled regressions with and without bank controls and the results

remain significant for banks bidding higher rates after the DLCR implementation and in MRO. We can conclude that in line with theory, Dutch banks adjust their behaviour in open market operations and bid higher rates and get allotted higher volumes after the implementation of the DLCR.

Table 3: **Regression results for interest rates bid in ECB tenders.** There are four independent variables out of which three are dummies. *DLCR implemented* and *DLCR transition* are dummies that are equal to one during the period when the DLCR is fully implemented, after 1 January 2004 and onward, and when the DLCR was partially implemented by banks, respectively, between 1 April and 31 December 2003. *MRO* is a dummy that is equal to 1 when the auction is a main refinancing operation and 0 when the auction is a long term refinancing operation. *Excess reserves* is the percentage of reserves held in excess by the banks in the sample. The dependent variable is the *Tender Rate Difference* between the volume weighted bid interest rate and the EU volume weighted bid interest rate, and is defined in percentage points. The daily sample runs from 2 January 2002 to 31 December 2004.

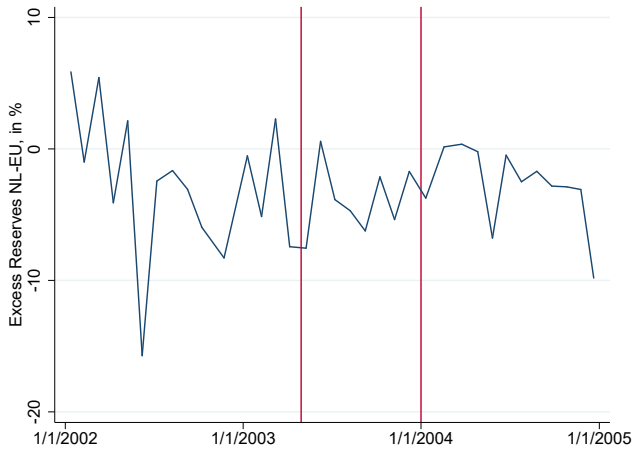
	(1)	(2)	(3)	(4)	(5)	(6)
DLCR_implemented	0.014***	0.013***	0.013***	0.015***	0.014***	0.016***
	(0.005)	(0.004)	(0.004)	(0.001)	(0.001)	(0.001)
DLCR_transition	0.001	-0.001	-0.001	-0.001	-0.001	-0.000
	(0.003)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
MRO		0.036***	0.036***	0.035***	0.036***	0.036***
		(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
MRO X DLCR_implemented		0.001	0.001	0.001	0.001	0.001
		(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Excess Reserves			-0.000	-0.000	-0.000	-0.000
			(0.000)	(0.000)	(0.000)	(0.000)
Constant	-0.041	0.075	0.075	-0.049***	-0.055***	-0.057*
	(0.526)	(0.406)	(0.409)	(0.003)	(0.003)	(0.030)
Observations	764	764	764	764	764	764
Number of banks	10	10	10	10	10	10
Bank FE	YES	YES	YES	YES	NO	NO
Bank Controls	YES	YES	YES	NO	NO	YES
r2 overall	0.21	0.44	0.44	0.41	0.40	0.42

*** p<0.01, ** p<0.05, * p<0.1, bank-clustered robust standard errors in parentheses

4.5. Excess reserves

In this section we study whether banks subject to the DLCR adjust their holdings of excess reserves after the announcement of the DLCR and after the implementation of the LCR. In Figure 3, we show that after the implementation of the DLCR, the difference between the banks' excess reserves subject to the DLCR and the EU peers decreases and becomes more stable. This raises questions about whether banks demand for central bank reserves is influenced by the introduction of a constraining liquidity metric. The potential implication of banks having a higher demand for central bank reserves and overall a smaller shortage of CB reserves is that it makes steering the short term interest rates – and thus inflation in a *scarcity model* – more difficult.

Figure 3: **Excess reserves.** This figure illustrates the difference between the average reserves held in excess by Dutch banks and their EU peers, in percentage points and over each maintenance period. The two vertical red lines mark the two dates of the staggered DLCR implementation.



In our regression, we use the blue line in Figure 3 as the dependent variable, or equivalently, in Equation (6) below:

$$Excess\ Reserves\ Difference_{i,t} = Excess\ Reserves\ Ratio_{i,t} - EU\ average\ Excess\ Reserves\ Ratio_t\ (in\ \%). \tag{6}$$

Banks' holdings of excess reserves is virtually not affected by banks' liquidity re-

quirements. Table 4 shows the effects of the transition towards and the introduction of the DLCR in the Netherlands on the amount of excess reserves banks hold compared to European peers. The results are not statistically significant and the lack of banks' adjustment of their levels of excess reserves is in line with our expectations and in line with theory by Bech and Keister (2017).

Table 4: **Regression results for excess reserves.** There are two independent variables. *DLCR implemented* and *DLCR transition* are dummies that are equal to one during the period when the DLCR is fully implemented, after 1 January 2004 and onward, and when the DLCR was partially implemented by banks, respectively, between 1 April and 31 December 2003. The dependent variable is the *Excess Reserves Delta* between the bank's excess reserve ratio and the EU average excess reserve ratio. The sample is from 2 January 2002 to 31 December 2004.

	(1)	(2)	(3)	(4)
DLCR_implemented	-1.543	0.887	0.887	0.448
	(2.688)	(1.278)	(1.278)	(1.321)
DLCR_transition	0.352	2.093	2.093	1.387
	(1.282)	(2.442)	(2.442)	(1.168)
Constant	-157.474	0.938	0.201	-1.867
	(181.234)	(1.108)	(1.487)	(26.220)
Observations	8,459	8,459	8,459	8,459
Number of banks	10	10	10	10
Bank FE	YES	YES	NO	NO
Bank Controls	YES	NO	NO	YES
r2 overall	0.022	0.017	0.001	0.020

Bank-clustered robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

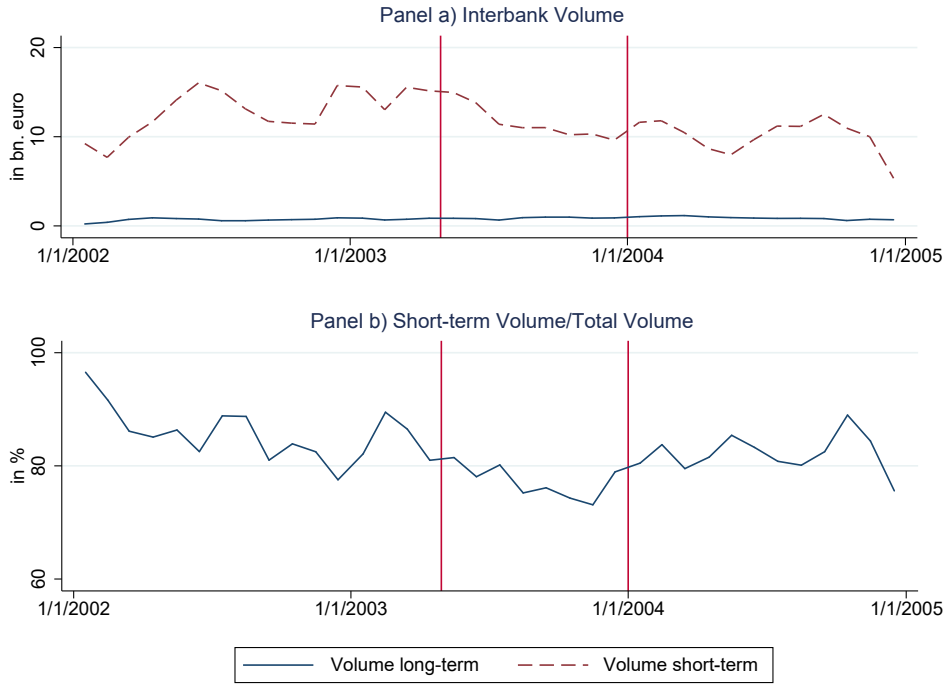
4.6. Interbank Market

In this section we study whether banks adjust their funding reliance on the short term interbank market after the implementation of the DLCR. Given the goal of the DLCR – incentivising banks to build a prudent 30 day liquidity buffer – the treatment of short term borrowings (maturities under 31 days) is less favourable than borrowings with maturities of 31 or more days. Therefore it is particularly interesting to study whether banks reduce the volume of short term borrowings.

Figure 4 plots the developments of prices and volumes in the interbank market. What is interesting, is the evolution of volumes of the short-term interbank loans

in Panel a). This illustrates a decreasing trend in volumes and thus a decreasing reliance on this type of bank funding in 2004, after the implementation of the DLCR for Dutch banks. The volume of long term loans briefly increases after the implementation of the DLCR but stabilises thereafter. This is not surprising since the funds obtained in the refinancing operations are more attractive from a pricing perspective.

Figure 4: **Trading volume in the unsecured interbank market.** Panel a) in this figure illustrates the average volumes borrowed by Dutch banks in the unsecured interbank market in the short term, with maturities under 31 days, and in the long term, with maturities of 31 days and longer. Panel b) illustrates the share of short term loans in the total borrowing volume in the unsecured interbank market. The two vertical red lines mark the two dates of the DLCR staggered implementation.



To study the effects on the short term funding volumes that banks borrow in the unsecured interbank market compared to the total funding obtained by banks in this market, we chose the blue line from Figure 4 as the dependent variable in our regression. We define the dependent variable in Equation 7 below:

$$ST\ Interbank\ Vol_{i,t} = \frac{Short-term\ interbank\ volume_{i,t}}{Total\ Interbank\ Volume_{i,t}}. \tag{7}$$

The significant results in Table 5 suggest that the banks' reliance on short term funding is decreasing after the announcement of the introduction of the DLCR, during the transition period. This is in line with theory and our *Hypothesis 3*. The short term funding in the unsecured interbank market requires additional holdings of HQLA to fulfill the DLCR, making this type of funding less desirable. The results of the model suggest that banks reduce their short term funding by 3,2% immediately after the implementation of the DLCR in what we call the transition period. This effect seems to disappear after January 2004. The results of the robustness and sensitivity analysis illustrated in Columns 2, 3 and 4 in Table 5 suggest that in the pooled specification of the regression, the reliance on short term funding in the interbank market continues to decrease and remains statistically significant.

Table 5: **Regression results for unsecured interbank short term borrowing.** There are two independent variables. *DLCR implemented* and *DLCR transition* are dummies that are equal to one during the period when the DLCR is fully implemented, after 1 January 2004 and on-wards, and when the DLCR was partially implemented by banks, respectively, between 1 April and 31 December 2003. *ST Interbank Vol* is defined as the share of short term funding volume a bank borrows in the unsecured interbank market in the total volume borrowed by the bank in this market. The sample is from 2 January 2002 to 31 December 2004.

	(1)	(2)	(3)	(4)
DLCR_implemented	-1.616	-4.279	-4.279	-8.773**
	(4.814)	(3.955)	(3.951)	(4.387)
DLCR_transition	-3.203*	-6.776***	-6.777***	-7.946***
	(1.848)	(2.316)	(2.315)	(2.583)
Constant	272.646	48.150***	83.415***	-134.116*
	(275.589)	(1.384)	(4.401)	(69.568)
Observations	5,027	5,027	5,027	5,027
Number of banks	10	10	10	10
Bank FE	YES	YES	NO	NO
Bank Controls	YES	NO	NO	YES
r2 overall	0.501	0.414	0.015	0.281

Bank-clustered robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

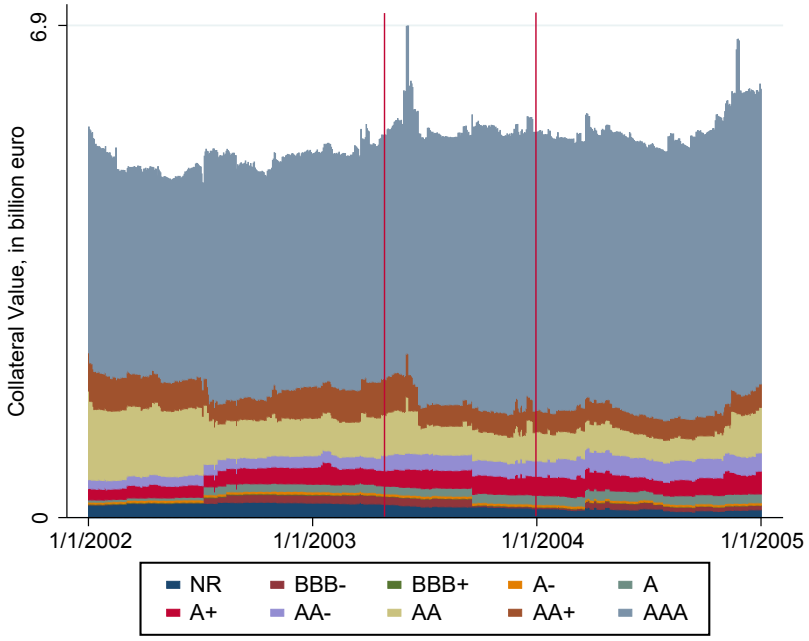
4.7. Extension: Collateral used in open market operations

In addition to quantities and prices in OMO and their reliance on short term funding, banks subject to the DLCR could also adjust the quality of collateral they pledge in open market operations. Unlike the analyses we have presented so far, we only have information on the collateral for Dutch banks and hence cannot compare with European peers. The results must thus be interpreted with some care.

4.7.1. Collateral Rating

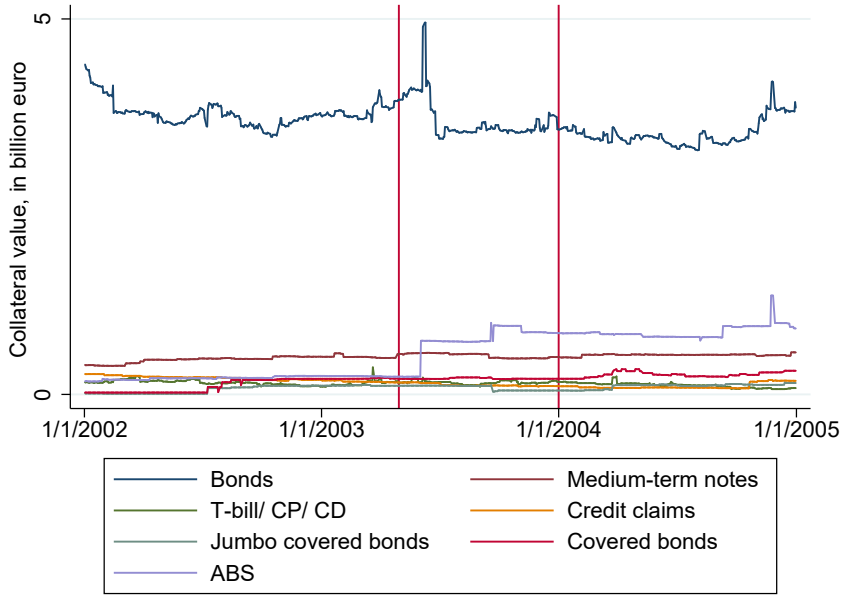
In order to access the open market operations, banks need to pledge collateral against the borrowed funds. We study whether the introduction of the DLCR impacts the choice of collateral quality banks pledge to the Eurosystem. In Figure 5 and in Figure 7 we plot the collateral volumes pledged by Dutch banks to the Eurosystem per rating category, and per asset type respectively. In both graphs we see that the value of total collateral pledged with the ECB increases slightly over time. This is visible especially after the implementation of the DLCR in April 2003 when there is a brief peak in the amount of collateral posted with the ECB. The total amount of collateral follows an upward trend thereafter as banks start to borrow more from the ECB. The credit quality of the collateral pledged with the Eurosystem changes slightly upwards over time. After the introduction of the DLCR it seems that there is more AAA collateral pledged to the Eurosystem.

Figure 5: **Collateral volume per rating category pledged with the Eurosystem.** This figure illustrates the collateral value pledged per rating category over time. The two vertical red lines mark the two dates of the DLCR staggered implementation.



In the period we analyse, certain assets pledged to the Eurosystem as collateral for refinancing operations have improved, and some have decreased in terms of credit quality. Notably, bonds have improved in credit quality, which are also the bulk of the collateral volume as shown in Figure 6 that illustrates volumes per asset type. Due to the large share of bonds in total collateral, improvements in their collateral quality would tilt the credit quality of the overall collateral portfolio towards an improvement.

Figure 6: **Collateral volume per asset type pledged with the Eurosystem.** This figure illustrates the value of collateral per asset type over time. The two vertical red lines mark the two dates of the DLCR staggered implementation.



We build the dependent variable for our regression as an index using the rating categories as shown in Equation 8. The lower the index, which ranges between 0 and 9, the higher the quality of the collateral pledged. The ECB maps the rating of the collateral to the best available rating in the market. The ratings are given by rating agencies. Only credit claims, which represent less than 1% of total, could be rated by the banks themselves if they have regulatory approved internal models.

$$Collateral_{i,t} = \frac{\sum_{j=1} Collateral\ Score_{j,i,t} * Collateral\ Value_{j,i,t}}{\sum_{j=1} Collateral\ value_{j,i,t}}. \tag{8}$$

Banks can make use of the collateral transformation possibility and pledge lower quality collateral during and after the implementation of the DLCR to use the central banks funds to comply with the new liquidity requirements, but they don't seem to do so. The results in Column 1 of Table 6 suggest that the collateral quality *increases* after the DLCR implementation, which is not in line with theory by Körding and Scheubel (2018), and contradicts *Hypothesis 4*. We conduct sensitivity

analysis for this effect in Column 2, 3 and 4 of Table 6 alternating bank controls and pooled data. The coefficients lose their statistical significance, however these three regression specifications do not have a better explanatory power than the first one.

Table 6: **Regression results for quality of collateral.** There are two independent variables. *DLCR implemented* and *DLCR transition* are dummies that are equal to one during the period when the DLCR is fully implemented, after 1 January 2004 and onward, and when the DLCR was partially implemented by banks, respectively, between 1 April and 31 December 2003. *Collateral* is defined as an index that ranges from 0 to 9, the higher the index the higher the quality of the collateral pledged on average by a bank, on a daily basis. The sample is from 2 January 2002 to 31 December 2004.

	(1)	(2)	(3)	(4)
DLCR_implemented	0.481**	0.232	0.231	0.315
	(0.224)	(0.283)	(0.283)	(0.246)
DLCR_transition	0.272**	0.147	0.145	0.169
	(0.1280)	(0.1792)	(0.172)	(0.150)
Constant	20.44	8.39***	7.79***	11.28***
	(34.05)	(0.14)	(0.25)	(2.16)
Observations	8,239	8,239	8,239	8,239
Number of banks	10	10	10	10
Bank FE	YES	YES	NO	NO
Bank Controls	YES	NO	NO	YES
rr2 overall	0.744	0.669	0.011	0.409

Bank-clustered robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.7.2. HQLA

We also study whether banks subject to the DLCR start posting more HQLA after the introduction of the DLCR by introducing the following variable the $HQLA_{i,t}$:

$$HQLA_{i,t} = \frac{Volume\ of\ HQLA_{i,t}}{Total\ Collateral\ Volume_{i,t}}. \tag{9}$$

We deepen our analysis and plot the share of high quality liquid assets in the total volume of collateral pledged for refinancing operations at the ECB in Figure 7. We

notice there is an increase in the share of HQLA posted after the implementation of the DLCR. Banks have the option to hold on to the HQLA to fulfill their DLCR requirements and pledge other types of collateral accepted by the ECB. It seems banks pledge HQLA to the ECB in exchange of reserves, which shows that there was enough HQLA available in the market and that the overall liquidity profile of the ECB collateral pledged by Dutch banks improved even after the implementation of the DLCR.

Figure 7: **Share of HQLA in total collateral pledged with the Eurosystem.** This figure illustrates the daily average share of collateral that qualifies as HQLA for fulfilling the DLCR in the total collateral pledged in the Eurosystem by Dutch banks. The two vertical red lines mark the two dates of the DLCR staggered implementation.

The results in Column 1 of Table 7 confirm that banks do not choose to post lower quality collateral to the Eurosystem after the implementation of the DLCR: contrary to our null hypothesis, the coefficients are not statistically significant. We expected to find that banks post a lower share of HQLA collateral to the ECB because the HQLA collateral can be used to comply with the newly introduced liquidity requirements. In Columns 2, 3 and 4 we perform a series of sensitivity analysis. We run both pooled and fixed effects regressions, with and without bank controls. The coefficients are not statistically significant, but for the bank controls.

Since bank controls seem to make the difference in Table 7 we would like to check if these results could be driven by a few banks. We split the sample of banks in

large banks and *small banks* based on the size of the banks. The large banks are the largest 3 Dutch banks and cover more than 70% of the banking assets in the country.

In Table 8 in Columns 1 to 4 we see that in the transition period of the DLCR, large banks post a higher share of HQLA collateral to the Eurosystem. Also after the DLCR has been fully implemented it seems that large banks post a larger share of HQLA collateral in OMO but the results are not significant in all cases. For small banks, in Columns 5 to 8, we do not find an effect as results are not statistically significant. All in all we cannot confirm that the theory by Körding and Scheubel (2018) or that *Hypothesis 5* hold empirically.

Table 7: **Regression results for HQLA holdings.** There are two independent variables. *DLCR implemented* and *DLCR transition* are dummies that are equal to one during the period when the DLCR is fully implemented, after 1 January 2004 and on-wards, and when the DLCR was partially implemented by banks, respectively, between 1 April and 31 December 2003. *HQLA* is the share of collateral that qualifies as HQLA in the total volume of collateral pledged by the bank to the Eurosystem. The sample is from 2 January 2002 to 31 December 2004.

	(1)	(2)	(3)	(4)
DLCR_implemented	2.451	-5.753	-5.754	2.862
	(7.240)	(8.253)	(8.248)	(6.949)
DLCR_transition	2.951	-2.908	-2.909	1.921
	(2.397)	(5.260)	(5.257)	(4.368)
Constant	642.82	96.08***	84.76***	228.38***
	(817.47)	(4.46)	(3.53)	(59.36)
Observations	8,459	8,459	8,459	8,459
Number of banks	10	10	10	10
Bank FE	YES	YES	NO	NO
Bank Controls	YES	NO	NO	YES
r2 overall	0.57	0.51	0.012	0.38

Bank-clustered robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8: **Regression results for HQLA holdings of small and large banks.** There are two independent variables. *DLCR implemented* and *DLCR transition* are dummies that are equal to one during the period when the DLCR is fully implemented, after 1 January 2004 and onward, and when the DLCR was partially implemented by banks, respectively, between 1 April and 31 December 2003. *HQLA* is the share of collateral that qualifies as HQLA in the total volume of collateral pledged by the bank to the Eurosystem. The sample is from 2 January 2002 to 31 December 2004.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	Large banks	Large banks	Large banks	Large banks	Small banks	Small banks	Small banks	Small banks	All banks
DLCR_implemented	2.55	4.00***	9.31***	9.31***	-1.96	-8.26	-10.83	-10.83	2.45
	(1.77)	(1.40)	(2.44)	(2.44)	(10.08)	(11.16)	(10.60)	(10.59)	(7.24)
DLCR_transition	2.12***	4.13***	5.99***	5.99***	0.90	-0.81	-5.92	-5.92	2.95
	(0.75)	(0.50)	(0.82)	(0.82)	(6.20)	(5.81)	(6.82)	(6.82)	(3.90)
Constant	-193.53	-503.06	91.14***	80.17***	753.05	384.83***	98.79***	86.34***	642.82
	(466.19)	(357.39)	(0.82)	(6.47)	(859.98)	(84.20)	(5.76)	(4.28)	(817.47)
Observations	2,307	2,307	2,307	2,307	6,152	6,152	6,152	6,152	8,459
Number of banks	3	3	3	3	7	7	7	7	10
Bank FE	YES	NO	YES	NO	YES	NO	YES	NO	YES
Bank Controls	YES	YES	NO	NO	YES	YES	NO	NO	YES
r2 overall	0.91	0.86	0.87	0.16	0.58	0.39	0.52	0.032	0.57

Bank-clustered robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

5. Conclusion

In this paper, we analyse a unique data set of quantitative liquidity requirements, individual bidding data of ECB's open market operations (OMOs) and collateral posted from the start of 2002 to the end of 2005, allowing us to compare banks' bidding behaviour prior and during the implementation of a liquidity constraint similar to the LCR. This historic perspective allows us to analyse the effects of the introduction of a quantitative liquidity requirement in a natural experiment setting not contaminated by extensive central bank interventions. Our findings can inform the currently ongoing ECB Strategy Review, that covers all parts of monetary policy.

First, we confirm the notion that banks bid higher volumes improving their success rates in auctions by 18% compared to EU peers. At the same time banks pay 1.3 basis points more in OMOs once they are subject to a liquidity requirement. Banks thus adjust their behavior and are willing to pay slightly more to secure their allotment in order to become compliant with the new liquidity requirement.

Second, in line with theory proposed by Bech and Keister (2017), we do not find evidence for banks' excessive holding of reserves to fulfill the LCR. In other words, we do not find evidence that the introduction of the LCR increases the demand for central banks reserves. If there would have been smaller shortages of central bank reserves, then steering the short term interest rates and, hence, inflation in a *scarcity model* would be more difficult. We do however find an indirect and significant relationship between the volumes bid by banks in OMO and their levels of excess reserves. The lower the level of excess reserves the higher their allotment rate in OMO, but this effect is not due to the introduction of the LCR.

Third, we find support for Bech and Keister (2017), and we show that the introduction of the liquidity requirement reduces participation and volume in short-term interbank money markets. This is evidence to support that Dutch banks adjust their funding mix after the introduction of the LCR. More specifically banks adjust their funding mix through an increased reliance on the ECB open market operations and a decline in short term wholesale market funding.

Fourth, there is generally a change in the quality of collateral posted in OMO. Banks post higher quality collateral to the Eurosystem, and large banks post a higher share of HQLA to the Eurosystem. This can partially be explained by the fact that the significant increase in the issuance of securitizations and covered bonds, that qualify both as HQLA and in the Eurosystem collateral framework, increased

the relative attractiveness of the OMOs vis-a-vis the alternative of refinancing via the interbank market. This increase in banks' holdings of HQLA could also explain to some extent the significant increase in banks' bid rates.

Finally, we do not find evidence to support Körding and Scheubel (2018) that expect a decrease in the quality of collateral posted in open market operations after the introduction of the DLCR. Nevertheless, this part of the analysis could benefit greatly from future research that incorporates collateral data for European peers as well.

To conclude, the LCR does not seem to impair the ability of central banks to implement monetary policy. However, the process by which central banks implement monetary policy might change, especially when considering returning to normal monetary policy without excess liquidity present in the markets. To correctly anticipate an open market operation's effect on interest rates will require central banks to consider not only the size of the operation, but also the way the operation is structured, how it impacts banks' balance sheets and the collateral framework.

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